An exclusive editorial supplement to JEMS developed in conjunction with the U.S. Metropolitan Municipalities EMS Medical Directors. Sponsored by ZOLL, Physio-Control Inc., American Red Cross, American Heart Association, Laerdal, and Advanced Circulatory.
CPR quality is crucial. In systems that have focused on improving CPR quality, both in and out of the hospital, survival rates from sudden cardiac arrest have doubled, or even tripled.\(^1\),\(^2\)

When it comes to assisting rescuers in providing the best CPR possible, no one is more experienced or can offer you as much as ZOLL®.

Learn more about the newest AHA Quality Consensus Statement, and how ZOLL technology can help you improve CPR quality at www.zoll.com/CPR.

Introduction
By A.J. Heightman, MPA, EMT-P

Airway Choices Matter
The effect of prehospital airway management on cardiac arrest outcomes
By Jason McMullan, MD & Justin Benoit, MD

The 5 Most Important Cardiovascular Topics
New studies provide insight on best prehospital treatment for patients
By Ashley Brown, MD; Jeremy Brywczynski, MD, FFAEM; Jared McKinney, MD; Laurie Lawrence, MD & Corey Slovis, MD, FACP, FACEP, FFAEM

Resusitating Beyond the 25-Minute Mark
Good neurological outcomes are likely in survivors of prolonged resuscitations
By James Dorroh, EMT-P; Patricia Overman, EMT-P & Benjamin Applebome, EMT-P

Consistent Compressions Count!
Mechanical CPR is producing resuscitation results beyond expectations
By Joseph Holley, MD, FACEP; Joseph P. Ornato, MD, FACP, FACC, FACEP & A.J. Heightman, MPA, EMT-P

A Tale of Three Successful EMS Systems
How coordinated ‘pit crew’ procedures have helped improve cardiac arrest resuscitations in the field
Wichita-Sedgwick County (Kan.) EMS: Sabina Braithwaite, MD, MPH; Jon E. Friesen, MS, EMT-P; Scott Hadley, MBA, BSN, RN, EMT-P & Darrel Kohls, BA, EMT-P
Austin-Travis County (Texas) EMS: Paul R. Hinchey, MD, MBA, FACEP; Michael Prather, EMT-P & Mark Karonika, EMT-P, FP-C
Wake County (N.C.) EMS: Brent Myers, MD, MPH, FACEP; William D. Holland II, BS, M.Div, EMT-P; Candice M. Eason, AAS, EMT-P & Justin Carhart, AAS, EMT-P

Staying on Time
A conversation about the importance of count & cadence of chest compressions
By Jeffrey M. Goodloe, MD, NRP, FACEP
Innovative & Cutting-Edge Resuscitation Practices

By A.J. Heightman, MPA, EMT-P

This special supplement to *JEMS*, prepared in cooperation with the U.S. Metropolitan Municipalities EMS Directors Consortium (aka, the “Eagles” Coalition), highlights some of the most important scientific advancements reported at the 2014 Gathering of Eagles Conference held in Dallas, Texas.

The Eagles Coalition has taken the lead in accelerating and driving the advancement of clinically proven care and resuscitation practice such as adult intraosseous (IO) infusion use in the prehospital arena, CPAP use in the field, and early STEMI and CATH lab notifications.

Eagles coordinator and course director, Dr. Paul Pepe, reflects that “the collective discussions, research and sometimes provocative initiatives carried out by the members of the group have not only advanced clinical medicine and affected countless EMS systems, but they also have substantially influenced in-hospital and emergency department care as well in terms of many changes in clinical management and procedures that were originally derived from the prehospital advances brought forth by members of the consortium.”

This *JEMS* EMS State of the Science supplement takes an in-depth look at significant research, advances in resuscitation practices, and the corresponding scientific data, presented at the 2014 conference. Each is the result of innovative and cutting edge processes, protocols and equipment implemented in many of the U.S. metropolitan municipalities.

In “Airway Choices Matter,” Jason McMullan, MD, and Justin Benoit, MD, take a close look at the effect of prehospital airway management on cardiac arrest outcomes.

Corey Slovis, MD, FACP, FACEP, FAAEM, and his colleagues at Vanderbilt University present “The 5 Most Important Cardiovascular Topics,” and make several key conclusions regarding various prehospital treatments and procedures, including therapeutic hypothermia, epinephrine’s role in CPR, O2 saturation levels, minimizing the pre-shock pause in CPR and the role of the prehospital ECG.

In “Resuscitating Beyond the 25-Minute Mark,” Brent Myers, MD, and key personnel from the progressive and innovative Wake County (N.C.) EMS System present significant findings and recommendations from data on successful Wake County resuscitations that should stop EMS systems from calling many cardiac arrests at the clinically-unproven 20 minute mark.

This epic article shows that good neurological outcomes are likely in survivors of prolonged resuscitations and points out that nearly 70% of survivors managed by the Wake County EMS system who were in arrest longer than 40 minutes from the time of dispatch were discharged from the hospital with a CPC of 1 or 2, and that meaningful neurological outcomes are not only possible, but in fact probable, in patients who survive cardiac arrest after extended resuscitations. In fact, the evidence from Wake County doesn’t support the concern that those who survive prolonged cardiac arrest will more than likely suffer severe neurological impairment.

In “Consistent Compressions Count!,” Joseph Holley, MD, FACEP, Joseph P. Ornato, MD, FACP, FACC, FACEP, and I present the facts and multiple case examples of how mechanical CPR is producing resuscitation results beyond expectations because of the consistency and minimal interruption in critically important blood flow these devices offer over manual CPR once activated.

The article shows the impact that the fast application and use of mechanical compression devices in Memphis (LUCAS 2) and Richmond, Va., (AutoPulse) aren’t only improving return of spontaneous circulation (ROSC) and resuscitation results but also resulting in patients who are so well perfused that they are exhibiting signs of good neurological response, blinking and answering the questions asked by paramedics during treatment and transport.

In another epic article, “A Tale of Three Successful EMS Systems,” we profile the dramatic increase in ROSC and neurologically intact discharge of patients in Wichita-Sedgwick County, Kan.; Austin-Travis County, Texas, and Wake County, N.C., as a result of highly coordinated “pit crew” resuscitation procedures.

Finally, in “Staying on Time,” Jeffrey M. Goodloe, MD, NRP, FACEP, points out the importance that count and cadence of chest compressions has on successful resuscitations. The use of inexpensive metronomes to keep personnel delivering compressions in the clinically significant range of 100–120 is pointed out in this important article.

This State of the Science supplement offers many EMS game-changing practices that should be reviewed with your medical leadership and response personnel to alter your care delivery and improve your resuscitation results.
Are You Providing Quality CPR?

Laerdal’s line of QCPR® training products can help with your CPR training program.

Find out more at laerdal.com/qcpr
Historically, endotracheal intubation has been the defining skill of a paramedic. Unlike EDs with ample time, space, lighting and resources, EMS providers are often forced to act immediately and in a less than ideal environment.

Out-of-hospital cardiac arrest is the classic case of forced action without time to prepare, and cardiac arrest victims are the most frequent EMS intubations. Recent conversations regarding cardiac arrest have focused on the importance of compression rate and depth, adequate recoil, peri-shock pauses, CPR density, “pit crew” modeling, mechanical compression devices and termination of resuscitation rules.

The American Heart Association even restructured the resuscitation alphabet to put “C” (Compressions) before “A” (Airway), all in the best interest of the patient. While paying attention to compressions is of prime importance, the criticality of airway management still remains. This article will focus on prehospital airway management and reaffirm its impact on cardiac arrest outcomes.

**By the Numbers**

Let’s put things into perspective. There are approximately 300,000 cases of out-of-hospital cardiac arrest in the United States every year:

- 80% will get an advanced prehospital airway;
- 30% will be left at the scene after termination of resuscitation;
- 33% will get return of spontaneous circulation (ROSC);
• 25% will get admitted to the hospital;
• 10% will survive to hospital discharge; and
• 6% will be discharged neurologically intact.

The Choice
There are essentially three options to choose from to manage the patient’s airway during out of hospital cardiac arrest: Use of a bag-valve mask (BVM), a supraglottic airway (SGA) (e.g., Combitube, LMA, King, SALT) and endotracheal intubation (ETI). ETI is the most common intervention, but there's growing support for SGAs as first-line airways, particularly to ensure that there are few interruptions in compressions during the early phases of resuscitation.

While some systems are very specific as to which method is used first, others allow the paramedic tasked with airway management to select the best device for the situation. Take a moment and reflect on your own practice, because the choices you make really do matter.

The Resuscitation Outcomes Consortium Experience
The Resuscitations Outcomes Consortium (ROC), a multicity North American research network, has focused on improving out of hospital cardiac arrest and trauma care. The ROC Prehospital Resuscitation Using an Impedance Valve and Early vs. Delayed (PRIMED) study, prospectively enrolled about 10,000 subjects and randomized them to early vs. late rhythm analysis and real vs. sham impedance threshold device.1

While ROC PRIMED doesn’t directly address the role of prehospital airway management, the robust nature of the study allowed investigators to perform a secondary analysis of the data. In this secondary analysis, 8,487 patients who underwent ETI were compared to 1,968 patients who had an SGA placed.2 Neurologically intact survival to hospital discharge was higher in those with ETI (4.7%) than those with an SGA (3.9%). After adjusting for many factors, such as age, initial rhythm and bystander CPR, the odds of survival were better for those with ETI (odds ratio of 1.4).

The odds for ROSC and 24-hour survival were also higher for patients with ETI and results persisted when patients with unsuccessful airway maneuvers were excluded.

A main limitation in interpreting these results lies in the source of the data. Agencies in the ROC undergo extensive and frequent training in out-of-hospital cardiac arrest care and may not be directly comparable to your system.

Also, these results are nested within a complex clinical trial and, although no difference was seen in the interventional arms of the trial, it’s difficult to know how those research interventions may have affected airway management. Regardless, in this group of patients, there’s a small but meaningful difference in outcomes based on how paramedics managed the patient’s airway.

The Japanese Experience
In 2013, a high-profile analysis of the All-Japan Utstein Registry was published in The Journal of the American Medical Association.3 Almost 650,000 patient records from a six-year period were analyzed and they concluded that BVM ventilation was associated with a 2.6 times greater chance of neurologically intact survival when compared to ETI or SGA placement.

The odds of achieving ROSC and one-month overall survival were also more common in patients managed with BVM and, similar to the ROC study, this was true even after adjusting for multiple patient factors.

In order to interpret their findings, though, the Japanese EMS system must be understood. Advanced life support, including ETI and SGA placement, is a relatively new skill. In fact, in this analysis, only 6% underwent ETI and 57% were managed with BVM alone; this sharply contrasts with common practices in the United States.

Additionally, approximately 18% of included cases suffered a traumatic arrest and these patients are expected to have dismal outcomes regardless of EMS interventions.

Finally, this analysis observed a low overall neurologically intact survival rate of 2.1%, which is approximately three times lower than in the U.S. Therefore, although specific airway management choices were associated with survival, there may have been other factors involved that altered the potential benefits of an airway procedure.

The Cardiac Arrest Registry to Enhance Survival Experience
The Cardiac Arrest Registry to Enhance Survival (CARES) was created in 2004 as a collaboration between Emory University, the Centers for Disease Control and Prevention and the American Heart Association. Since that time, CARES has grown to include 40 participating communities in 25 states and has collected data on more than 73,000 cases of out-of-hospital cardiac arrest.

Similar to the Japanese registry, CARES allows insight into the broad practice of cardiac arrest resuscitation and presents an opportunity to
explore the relationship between prehospital airway management and outcomes in the U.S.

An analysis of this database looked at almost 11,000 patients with out-of-hospital cardiac arrest in the calendar year 2011 and showed similar results to those seen in Japan. Patients who didn’t undergo advanced airway placement had better neurologic outcomes than those who received ETI or SGA (18.6% neurologically intact survival for BVM, 5.2% for SGA and 5.4% for ETI).

This was most true in patients found in initially shockable rhythms. In addition, similar to the ROC study, when the treating EMS providers decided to place an advanced airway, patients found in shockable rhythms had better neurologically intact survival with ETI compared to SGA.

There was no difference seen between ETI and SGA for cases of primary asystole or pulseless electrical activity.

**Your Choice Matters**

Balancing all of this information can be difficult because, unless you are part of the ROC, CARES or practice in Japan, these results may not be directly applicable to your personal practice. However, these three studies all show that prehospital airway management is significantly associated with neurologic outcomes. Your choice matters.

**Association Doesn’t Equal Causation**

All of this evidence comes from a retrospective look back at how patients were treated, without knowing the details of the resuscitations or the thought process behind each individual decision by the treating EMS providers.

Most likely, our “one-shock wonders” with immediate return to consciousness after initial defibrillation are all included in the groups that had no advanced airway, because there was no need for an airway; this could bias the “no airway group toward better outcomes.

However, the no airway group is also the default for all patients where attempts at airway placement failed, and it’s plausible that these patients could have the worst outcomes because of inherent interruptions in chest compressions that occur with airway maneuvers.

Honestly, there are unmeasured and unmeasurable factors that influence both the airway decision and the patient’s outcome no matter how hard you try to control for them, which is why a causal relationship is difficult to determine.

A common mistake in interpreting these results is confusing association and causation. Crudely, association means that two things are related in some way or are often found together, whereas causation implies a definite cause-and-effect relationship.

Consider this example: Use of lights and sirens is associated with ambulance crashes. Lights and sirens don’t cause ambulance crashes. So, the strongest conclusion we can make from these studies is that prehospital airway management and neurologically intact survival are linked. The challenging next step is determining why?

**Trust. Professionalism. Perfection.**

There’s a divine contract between you and your patient when you manage their airway. We all know the Rifleman’s Creed: “This is my rifle. There are many like it, but this one is mine…”

We must treat our laryngoscope and everything else in our airway bag in the same way. We must move beyond the technical skill of airway management and toward an understanding of what happens during and after we manage an airway. After all, pulling a trigger may itself be quick, easy and harmless, but the potential repercussions can be devastating.

**Positive Pressure Ventilation is the Devil …**

The inevitable and immediate physiologic change that occurs after ETI or SGA placement is the conversion from normal negative pressure ventilation to abnormal positive pressure ventilation. In the apneic patient, ventilation by a BVM has the same effect on physiology.

In a normal, healthy person the diaphragm drops during inhalation, the thorax expands and air is drawn into the lungs due to a decrease in intrathoracic pressure. Often overlooked is the fact that the drop in intrathoracic pressure during normal respiration also augments venous return to the heart, increasing preload. This facilitates adequate perfusion of the brain.

The opposite occurs with positive pressure ventilation. Intrathoracic pressure abnormally rises when we ventilate a patient through an advanced airway or with a BVM. The consequences are significant: venous return falls, preload decreases and cardiac output declines. Thus, every positive pressure breath limits coronary and cerebral perfusion. In addition, even optimized chest compressions during cardiopulmonary resuscitation fall far short of matching normal cardiac output, which further decreases blood flow to the brain.

**… and Hyperventilation is His Bride**

We all tend to hyperventilate our patients.
Physicians, nurses, respiratory therapists, paramedics and EMTs—no one is immune. Often we do it subconsciously. Sometimes we do it in an effort to make up for hypoxia due to prolonged apnea time. (This logic is wrong, by the way, because increasing the respiratory rate does not improve oxygenation.) No matter what the reason, hyperventilation is always wrong in cardiac arrest management.

Hyperventilation causes hypocarbia, and this decrease in the carbon dioxide in the blood leads to vasoconstriction of the cerebral vessels. We use this to our advantage in the severe traumatic brain injury patient who is herniating. However, in patients suffering from cardiac arrest, this phenomenon is adding insult to injury because cerebral perfusion is already compromised by use of positive pressure ventilation.

Do No Harm (and Do “Know” Harm)

Treatment priorities are established as soon as the first rescuer reaches a patient in cardiac arrest and each decision made should be done to maximize the chance of neurologically intact survival.

We all agree that high-quality, uninterrupted chest compressions are absolutely essential, and rapid treatment of shockable rhythms is arguably the highest of all priorities. The three studies highlighted above lend support to deemphasizing airway management, but, eventually, the airway is almost always actively managed.

Consider these suggestions:

1. Resurrect the art of BVM ventilation. This skill is harder than we remember. Practice today, tomorrow and at least as often as you practice other airway skills. If you have enough personnel, allocate two providers for rescue breathing and use the two-handed thumbs down technique to hold the mask. Also, using bilateral nasopharyngeal airways and an oropharyngeal airway truly helps.

2. Use feedback devices whenever possible to avoid hyperventilation. Capnography is the best method, because airway placement is confirmed with each breath and the respiratory rate can be visualized. Metronomes, flashing timer lights and tactile feedback resuscitation bags are also reasonable adjuncts.

3. Finally, pay attention to your crew’s approach to airway management. Multiple providers making multiple attempts at ETI isn’t acceptable if high-quality continuous chest compressions are compromised. Even a single successful attempt may harm the patient in the long run if compressions are interrupted or hypoxia time is prolonged. Some airways are truly difficult, but the key is to always optimize your environment and make it count.

The Bottom Line

Although the best methods for resuscitation may differ from one EMS system to another, EMS airway management will always be a critical component of cardiac arrest management. We may not know exactly why, but it’s clear that your choices have downstream impacts on survival and quality of life. ETI may be beneficial in some patients, whereas a BVM may suffice in others.

No matter which ventilation method is used, you must monitor the effect and guide your team to provide effective ventilations, just as you guide them for effective compressions.

Why do all this? Because, selfishly, I may be one of the lucky ones who survives my first death; and I want my brain fully functional in-between.

Jason McMullan, MD, is the associate director (research) for University of Cincinnati’s Department of Emergency Medicine Division of EMS and is the director of the fellowship in EMS medicine. His career started as a volunteer EMT with North Mecklenburg Rescue Squad (Charlotte, N.C.) in 1997, and he’s currently part of the medical direction team for Cincinnati, Blue Ash, Forest Park and Green Hills Fire Departments (Ohio). He may be contacted at Jason.McMullan@uc.edu.

Justin Benoit, MD, is an assistant professor of emergency medicine and an EMS research fellow at the University of Cincinnati. His career started as a volunteer EMT/firefighter with the Berwyn Heights Volunteer Fire Department in Prince George’s County, Md. He’s currently the Associate Medical Director for the Montgomery (Ohio) Fire Department, a flight physician for University of Cincinnati Medical Center’s Air Care and a tactical physician for the Cincinnati Police Department.

References


I mportant studies and publications relevant to EMS providers are appearing at an ever increasing frequency. In this article, we review what we believe to be the five most important cardiovascular topics that have appeared in the literature over the past year.

They are: 1) new and emerging evidence on how and when to optimally provide therapeutic hypothermia; 2) the effectiveness of epinephrine in cardiac arrest; 3) the potential toxicity of oxygen in prehospital care; 4) optimal CPR techniques for the year 2015; and 5) incremental understanding on the role of prehospital ECGs.

**Therapeutic Hypothermia**

Since 2005, both the American Heart Association and the European Resuscitation Council have stated that therapeutic hypothermia (TH) is indicated for patients who survived cardiac arrest from v fib and v tach.1

Until recently, cooling to a temperature of 32–33 degrees C post cardiac arrest was considered the standard of care and a number of EMS systems were even beginning this therapy in the field prior to ED arrival. Two recent studies have begun to refine our understanding on the use and application of TH post cardiac arrest.

**Study #1:** The first article is a large multicenter European trial that compared “deep” TH at 33 degrees C to “mild” TH at 36 degrees C.2 The authors analyzed the results from 939 patients randomized to either of these temperatures.

The major finding of this article was that there was no benefit to cooling patients deeply to 33 degrees C vs. just cooling them mildly to 36 degrees C. At six month follow-up, 54% of the 33 degree C patient group had died or had a poor neurologic outcome (50% dead) vs. 52% of the 36 degree C patients (48% dead).

Of note, about 20% of the included patients from both groups had non-v fib/v tach arrest. There were no differences between the 33-degree C vs. 36-degree C cooled patients when each group’s patients were compared or when the non-v fib/v tach patients were compared.

Because this study prevented patients from developing a fever in either group for the first three days of the study, the authors have now begun to question whether TH is as important as preventing hyperthermia post arrest. At the
present time, however, this reasoning that TH isn’t effective and that only fever prevention makes a difference, is purely speculative.

What does appear to be true is that TH doesn’t need to be as deep as first thought and that mildly cooling a patient to just 36 degrees C may be all that is requested.

**Study #2:** The second major study to appear in the past year comes from Seattle and King County, Wash.³ Researchers from the University of Washington evaluated whether beginning TH immediately post cardiac arrest in the field provided added benefits vs. awaiting in-hospital initiated therapy.

They randomized 1,359 patients over a five-year period to either EMS-begun TH or standard prehospital post-arrest care to 583 status/post (s/p) v fib patients and 776 non-shockable rhythm arrest patients, all of whom had return of spontaneous circulation (ROSC) but weren’t awake and responsive.

The authors found no benefit to the early, in-the-field initiation of TH by EMS providers vs. those who had TH begun after hospital arrival. Patients who received up to 2,000 cc of EMS-administered normal saline that had been cooled to 4 degrees C, had no better outcomes than those patients who received no EMS cooling.

A nearly identical 62.7% of the prehospital cooled s/p v fib patients were discharged versus 64.3% of the s/p v fib non-cooled EMS patients. There was no benefit seen in the non-v fib patient subgroups and no neurological benefits were seen in those patients who were cooled in the field.

Thus, even though the EMS-cooled patients arrived at the hospital with a reduced core temperature of more than 1 degree C compared to non-cooled patients and took one hour less to achieve targeted TH core temperatures, they had no improved survival or improved neurological outcomes.

It should also be noted that prehospital cooling was associated with increased rearrests during EMS transport and an increased incidence of pulmonary edema during the first hospital day.

Thus, as we approach 2015, the exact role of TH has become somewhat unclear. It appears that starting TH in the field offers no benefit in EMS systems with the relatively short transport times seen in typical urban and suburban systems. Once s/p v fib/v tach patients reach the hospital, if they have ROSC but can’t respond meaningfully, TH is indicated and likely needs to be at only 36 degrees C.

It’s not currently clear if there’s any benefit to deeper TH at 32–33 degrees C and some are now questioning if TH is beneficial or merely preventing fever s/p arrest. Finally, regardless of what temperature is used for comatose survivors of v fib/v tach arrest patients who obtain ROSC should rapidly go to the cardiac catheterization laboratory regardless of whether their ECGs show an ST elevation myocardial infarction (STEMI) or not.⁴

---

**2 Epinephrine in Cardiac Arrest**

The role and efficacy of epinephrine has begun to be questioned. Although it has been central to the therapy of pulseless patients in cardiac arrest, its true value has never been rigorously studied in large, randomized, placebo-controlled human trials.

**Study #1:** Between the years of 2007–2010, the Japanese performed a large study in an attempt to answer the question as to the benefit of epinephrine in prehospital cardiac arrest.⁵

Studying all witnessed cardiac arrests in the entire nation over the time period, they compared outcomes of patients who received epinephrine vs. those who didn’t receive epinephrine. There were almost 2,000 pairs of patients with an initial rhythm of v fib/v tach who did and didn’t receive epinephrine, as well as almost 10,000 pairs with an initial rhythm of pulseless electrical activity (PEA) or asystole.⁵

The study found that there was increased ROSC with the prehospital administration of epinephrine in v fib/v tach (17% vs.13.4%), however, and likely more important, there was no increase in neurologically intact survival at discharge. This again stresses the importance of early defibrillation and high-quality CPR in v fib/v tach arrest as opposed to a priority on the administration of adrenaline in arrest.

When PEA and asystole were studied, results were predictably dismal. The prehospital administration of epinephrine did improve ROSC as with v fib/v tach (4% vs. 2.4%), but only improved neurologically intact survival at one month by 0.3% (0.7% vs. 0.4%).

**Study #2:** In another study looking at epinephrine’s efficacy, physicians and scientists in Australia noted there was little evidence epinephrine improved neurologically intact survival in cardiac arrest patients, so they also embarked on a randomized, double-blind, placebo-controlled trial to test this medication’s efficacy.⁶

This type of trial is considered the highest quality in research. Over the course of the study period, 262 patients received 1 mg of placebo
during prehospital ACLS resuscitation and 272 received actual epinephrine. This study demonstrated that there was an increase in ROSC when epinephrine was given. However, looking downstream, there was no difference in survival to hospital discharge in patients receiving epinephrine or placebo by prehospital providers.

In another study, researchers analyzed all prehospital studies currently available that used standard epinephrine, high dose epinephrine or vasopressin in cardiac arrest.7 There were 14 studies included with more than 12,000 patients. There was no survival to discharge benefits or neurologic outcome differences in any group studied.

Thus, at the present time, epinephrine’s exact role and effectiveness remains unclear. However, following the current ACLS recommendation seems most prudent, until there’s consensus on changing its current dose, role or when to administer it. Perhaps, as noted below, adding additional medications to epinephrine is the answer.

Other treatment options in cardiac arrest:
So, if epinephrine doesn’t provide significant benefits in cardiac arrest when used alone, are there any promising treatment options for EMS providers? Scientific theory suggests that vasopressin and steroid administration may provide protection of the brain in cardiac arrest, which epinephrine alone cannot accomplish.

Recently, a Greek study evaluated the administration of vasopressin, steroids and epinephrine (VSE) in a bundle during cardiac arrest.8 Of the more than 250 patients receiving this therapy compared to traditional treatment, VSE therapy resulted in increased ROSC as well as increased survival to discharge (13.9% vs. 5.1%). Although these were inpatients, this is very promising research and may become standard of care in the near future for resuscitation.

Oxygen Therapy
For years oxygen has been the standard therapy for critically ill patients encountered in the prehospital setting. However, based on recent literature, it’s time to rethink the routine application of high-flow oxygen to non-hypoxemic patients in cardiac and non-cardiac emergencies. Not only does raising the PaO2 have little to no benefit on oxygen delivery when hemoglobin is already fully saturated, but hyperoxia can also deleteriously alter hemodynamics.

Hyperoxia is defined as a blood oxygen tension significantly above normal. Blood that’s 100% saturated at room air has an oxygen tension of about 100 mmHg. Giving oxygen, especially by a 100% non-rebreather mask or 100% O2 by endotracheal tube, won’t change the O2 saturation but can raise O2 tensions by hundreds of mmHg.

Hyperoxia, especially above 300–350 mmHg, can result in the formation of reactive oxygen species which can trigger inflammation and worsen reperfusion injury. This is true for a myriad of conditions including acute myocardial infarction, stroke, traumatic brain injury, chronic obstructive pulmonary disease (COPD) and cardiac arrest.

In patients suffering from acute myocardial infarction, hyperoxia can increase systemic vascular resistance while at the same time decreasing cardiac output and stroke volume.9 These effects worsen coronary blood flow and further impair oxygen delivery to the cardiac microcirculation.

It’s also been shown that patients who suffer sudden cardiac arrest have increased mortality and worse neurologic outcome when ROSC is achieved if they’re exposed to supra-normal oxygen levels.10 This may again be a result of cerebral and myocardial vasoconstriction or the contribution of hyperoxia to the post cardiac arrest syndrome.

Based on these findings, EMS providers should be sure patients with chest pain or ECG changes consistent with ischemia or infarction have their O2 saturations titrated into the mid-90s, but not aim for saturation levels of 98–100%. We should all certainly avoid high-flow O2 by mask in patients with good oxygen saturation to begin with.

Just like in cardiac patients, hyperoxic-induced vasoconstriction can also worsen oxygen delivery to damaged tissue in the brain. This, coupled with the formation of oxygen free radicals, can worsen outcome in patients suffering from stroke or traumatic brain injury.11–13
Rincon and colleagues recently evaluated how different levels of oxygenation can affect acute cerebrovascular accident (CVA) patients who had suffered an ischemic stroke, hemorrhagic stroke or subarachnoid hemorrhage.

They divided these CVA patients into three groups: hyperoxic; hypoxic and normal oxygen tension. They found that mortality with abnormal oxygenation was increased vs. those patients with normal oxygenation.

Mortality was 60% in the hyperoxic group, 53% in the hypoxic group and 47% in those with normal oxygenation. Surprisingly, mortality was higher with very high oxygen tensions than in hypoxic patients and hyperoxia was an independent predictor of death.

Another common situation in which oxygen is reflexively administered and not often carefully monitored is in the patient with respiratory distress from COPD. It’s understandable why this occurs, as patients with severe COPD often exhibit significant air hunger and high-flow oxygen seems appropriate. While this patient population is at risk for hypoxia, there’s also legitimate risk from hyperoxia as a result of the administration of 100% oxygen, as is commonplace.

In 2010, Austin and colleagues compared high flow oxygen with titrated oxygen in the treatment of patients with presumed COPD exacerbations in the prehospital setting. This study demonstrated a mortality rate of 2% in patients with COPD who were treated with titrated oxygen (target O2 sat of 88–92%) vs. 9% with standard high-flow O2. This more than four-fold increase in mortality is likely the result of hyperoxia diminishing the hypoxic respiratory drive in patients with COPD.

This increase in oxygenation depresses respirations, resulting in hypercarbia and respiratory acidosis. It may also increase ventilation-perfusion mismatch in patients already in respiratory distress.

It’s therefore crucial that EMS providers pay close attention to how much oxygen critically ill patients receive in the prehospital setting.

The time for the blind administration of oxygen has passed and we strongly believe that EMS providers should target an oxygen saturation of approximately 94–95% and 89-92% for those with severe COPD.

Despite advances in technology and drug therapies, survival rates for out of hospital cardiac arrest in the U.S. remain dismal, with less than a 15% overall survival rate. Studies have consistently shown that high-quality CPR improves survival.

By focusing on the delivery of high-quality CPR, many EMS systems have made dramatic improvements in neurologically intact survival rates.

The American Heart Association has identified five critical components of high-quality CPR:

1. Chest compression fraction (CCF): Chest compression fraction is the proportion of time chest compressions are performed during the cardiac arrest. The goal of CCF is at least 80%, therefore it is essential to minimize interruptions of chest compressions.
2. Chest compression rate: 100–120 compressions per minute is the optimal manual compression rate in both adults and children. Anything above or below this range will decrease cardiac output, coronary perfusion and, ultimately, neurologically intact survival.
3. Chest compression depth: Compression depths of 2 inches (50mm) in adults, and 1/3 the chest anterior-posterior dimension in infants and children are the minimum compression depths needed to ensure optimal CPR efficacy.
4. Full chest recoil: It’s essential not to lean on the chest during recoil so that full re-expansion of the chest cavity and lungs can occur. This will maximize venous return during relaxation and allow maximal cardiac output during compression.
5. Avoid excessive ventilation: By delivering between 6–12 breaths per minute, the lungs aren’t expanded for much of the compression fraction. Thus, the less the lungs are expanded, the more blood will be returned to the heart. Positive pressure ventilation lowers cardiac output, therefore tidal volumes need only to produce a small visible rise in the chest wall.

The recent literature has demonstrated that the consistent delivery of high-quality CPR requires constant performance monitoring and feedback. Even well-trained providers fail to consistently deliver high-quality CPR. Systemic continuous quality improvement programs should be implemented to monitor CPR quality and resuscitation outcomes.

Remember the adage: “If you don’t measure it, you can’t improve it.” CPR is a team endeavor and CPR performance is enhanced when team members have a designated leader and clearly defined roles.

Strong team leadership requires orchestration.
of tasks with the focus toward delivering high-quality CPR. All tasks requiring interruption of chest compressions should be done simultaneously, modeling the “pit crew” teams in auto racing.

Recent studies have also demonstrated the importance of the “peri-shock pause” and rates of survival after a cardiac arrest.\(^\text{16, 17}\) The “peri-shock pause” is defined as the time interval from the cessation of compressions to the time of defibrillation (pre-shock time) plus the time from shock to resumption of chest compressions (post-shock time).

Limiting the pre-shock interval to less than 10 seconds and the peri-shock interval to less than 20 seconds improves outcomes. There was an approximate 50% increase in survival when the pre-shock pause was less than 10 seconds as compared to those whose pre-shock pause was greater than 20 seconds.\(^\text{2}\)

Interestingly, the length of the post-shock interval has not been found to play a role in survival. The pre-shock pause can be shortened by pre-charging the manual defibrillator during the last five seconds of the CPR cycle before the rhythm check. This will eliminate the time needed to charge the defibrillator after a shockable rhythm is detected.

In a recently published study, doing compressions while the machine was charging decreased the pre-shock pause from 15 to 3.5 seconds and improved the compression fraction by almost 10%.\(^\text{17}\)

When using an AED, compressions during charging will decrease the peri-shock pause. Unfortunately, the ability for the AEDs to reliably interpret a rhythm and charge during compressions isn’t yet widely available.

In summary, there are five critical components of manual CPR that help to define the delivery of high-quality care during a cardiac arrest. It’s also important to remember that CPR is a team endeavor and requires leadership and clearly defined roles in order to maximize performance.

Continuous monitoring and feedback on CPR performance is essential. Recent studies have illustrated that strategies geared toward limiting the peri-shock pause improve survival.

### 5 Prehospital ECGs

Obtaining and interpreting prehospital ECGs is an essential skill for a paramedic, yet sensitivity and specificity among different EMS systems varies for identifying STEMI. Many systems use paramedic interpretation, often coupled with automated interpretation of the ECG, while others also include transmission to base station for physician interpretation.

Studies have found that paramedics are best at interpreting inferior STEMI (96%), followed by anterior STEMI (78%); however, only about 51% correctly recognized a lateral STEMI.\(^\text{21}\) (See Figure 1).

Although paramedics continue to be more expert in recognizing STEMIs, there’s the potential for falsely labeling STEMI mimics, such as bundle branch blocks, LVH and paced rhythms as STEMIs,\(^\text{21}\) as well as failing to recognize hyper-acute T waves, Wellen's syndrome and posterior STEMIs.\(^\text{18}\)

Based on these findings, we believe all EMS systems should focus on teaching their paramedics to become experts in reading ECGs for STEMIs and also to transmit ECGs to the receiving hospital for physician review. Rather than focusing on all STEMI patterns, including high lateral, posterior and right ventricular, a recent article demonstrated that prehospital STEMIs are mostly composed of inferior (55%) and anterior (41%) patterns, and educational efforts should be focused on these two patterns. We believe it’s pointless to debate whether systems should transmit their prehospital ECGs for STEMI confirmation, but believe strongly that systems should aim for optimal teamwork where paramedic ECG interpretation, computer ECG read and ED doctors all work together in deciding whether the PCI team should be activated.

Much more effort should be devoted to improving the number of STEMI patients who receive prehospital ECG, as a recent study showed that only 47–55% of STEMI patients brought in by EMS have an ECG recorded.\(^\text{24}\) The importance of prehospital ECGs cannot be overstated. In a recently published meta-analysis of 16 studies involving 14,000 patients, prehospital ECGs
decreased mortality by 37% and reduced door-to-balloon times by between 21–78 minutes.25

Obtaining and potentially transmitting a prehospital ECG in patients with the potential for acute coronary syndrome (ACS) is important even when initial ECG doesn’t show STEMI.

In one study, 11% of patients who were eventually diagnosed with a STEMI initially had a nondiagnostic ECG.19 Of these patients, 72.4% developed STEMI on ECG within 90 minutes of initial ECG, underlying the importance of repeating ECGs during transport in patients with symptoms highly suspicious for ACS and, in particular, those patients whose symptoms change en route.19

Oppositely, between 3–22% of patients with initial STEMI on ECG may have resolution of ST-elevation by the time they get to the ED.20,23 This may be due to spontaneous reperfusion and/or prehospital treatments; however, these patients remain at high risk of reocclusion and should be treated as STEMI patients.

Even if patients don’t have a STEMI on initial ECG or by the time they get to the ED, prehospital ECGs have great value. In another recent study from Ontario, 281 prehospital ECGs of patients without STEMI were evaluated. Of these, 12.3% had clinically significant abnormalities that weren’t present by the time the patient arrived at the ED, such as ST depression, T-wave inversions or arrhythmias.22

Of these abnormalities, 65.7% changed physician management.22 Another 21 prehospital ECGs weren’t different than the initial ED ECG, but influenced patient management prior to obtaining initial ECG (such as early consultation or treatment). In this study, a total of 18.5% of prehospital ECGs changed or influenced ED physician management.22

In summary, prehospital ECGs are increasingly common and the expertise of interpretive skills of paramedics continues to increase. Systems should specifically focus on paramedic expertise in reading anterior and inferior STEMIs, preferentially, as these two patterns are by far the most common STEMI patterns seen.

Optimal care is more likely when the paramedic, the computer and the ED physician are all interpreting the prehospital ECG as a team. And finally, the prehospital ECG has great value, even if it doesn’t show a STEMI, as it can be compared to the ED’s ECG and serial ones obtained later. One ECG begets another!

In Closing

We close this article with five summary statements:

1. Therapeutic hypothermia started in the prehospital setting doesn’t appear to have any proven benefits and once the patient arrives at the hospital, mild hypothermia to just 36 degrees C, rather than 32 degrees C, may become the new standard of care.
2. Epinephrine’s role in CPR remains unproven and it may be that it’s more effective if combined with vasopressin and, perhaps, steroids.
3. Oxygen isn’t a benign drug and EMS providers should aim for an O2 saturation of 94–95% in most critically ill patients, rather than 100%, and aim for just 89–92% in those patients with significant COPD.
4. CPR needs to be performed meticulously well with a focus on minimizing the pre-shock pause by performing compressions during charging and adherence to a
 compression depth of at least 2 inches and a rate of 100–120 compressions per minute.

5. The prehospital ECG has great value even if it doesn’t show a STEMI as it can be used for comparison purposes with one or more EMS or in-ED ECGs. “One ECG begets another.”

Ashley Brown, MD, is on the faculty in the department of emergency medicine at Vanderbilt University School of Medicine. She’s a former EMS fellow and is an active flight physician for the Vanderbilt LifeFlight aeromedical program.

Jeremy McKinney, MD, is an assistant professor of emergency medicine and is medical director of event medicine for Vanderbilt University School of Medicine. He’s also an assistant medical director for the Nashville Fire Department.

Laurie Lawrence, MD, is an assistant professor of emergency medicine and pediatrics at Vanderbilt University School of Medicine. She’s assistant medical director of pediatric EMS for the Nashville Fire Department.

Corey Slovis, MD, FACP, FACEP, FAEM is a professor and chair of emergency medicine at Vanderbilt University School of Medicine and serves as the medical director for the Nashville Fire Department and Nashville International Airport. He’s also a member of the JEMS editorial board.

References


STUDIES SHOW 25% MORE NEUROLOGICALLY-INTACT SURVIVAL FROM CARDIAC ARREST

Give your patients MORE

When you combine high quality CPR with the ResQPOD® Impedance Threshold Device, your patients get more. Attached to an airway during CPR, the ResQPOD enhances negative pressure in the chest to pull more blood back to the heart and lower intracranial pressure non-invasively.

Studies show:

- 25% or MORE Increase in Neurologically-intact Survival
- 50% MORE Blood Flow to the Brain
- 100% MORE Blood Flow to the Heart

Studies available upon request. The generally cleared indication for the ResQPOD ITD available for sale in the United States (US) is for a temporary increase in blood circulation during emergency care, hospital, clinic, and home use. Research is ongoing in the US to evaluate the long-term benefit of the ResQPOD for other specific indications. The studies referenced here are not intended to imply specific outcomes-based claims not yet cleared by the US FDA.
On a hot summer afternoon in Raleigh, N.C., paramedics from the Wake County EMS System (WCEMSS) respond to a middle-aged man lying pulseless and apneic next to his truck on the shoulder of an interstate. The Raleigh Fire Department personnel who were first on scene had witnessed the patient suffer cardiac arrest after vomiting his sports drink. They initiated CPR and shocked the patient twice with an automated external defibrillator (AED) prior to EMS arrival.

Paramedics place the patient on a cardiac monitor and observe ventricular fibrillation, prompting a third shock and continued CPR. EMS and first responders work as a team to provide aggressive resuscitation in an effort to save the man’s life.

Good neurological outcomes are likely in survivors of prolonged resuscitations

By James Dorroh, EMT-P; Patricia Overman, EMT-P & Benjamin Applebome, EMT-P
CPC 2 patients are able to care for themselves and work despite their moderate cerebral impairment; CPCs 1 and 2 are thus both categorized as “good” neurological outcomes.

It’s reasonable to consider whether protracted time in cardiac arrest—even in the presence of refractory v fib, as exhibited by the man who coded beside the highway—is predictive of poor neurological outcomes ranging from severe cerebral disability to brain death.

No provider wants to resuscitate a patient only to have him remain comatose for the rest of his life. In lengthy codes, then, is there a point at which cardiovascular survival may still be achievable, but the potential for quality of life is so low that further efforts should be considered neurologically futile?

Out with the Old …

Examination of the last decade’s trends in out-of-hospital cardiac arrest management provides context for the discussion of neurological survivability. Prior to 2005, WCEMSS ran codes according to the standard of care at the time. Providers who practiced in that era will likely recall the former approach of 15:2 compression-to-ventilation ratios, stacked shocks, early intubation, IV access, administration of two rounds of drugs, load the patient and go to the hospital.

Defibrillation, intubation and diesel therapy were the primary focus. Paramedics simply did not work codes on scene. It seemed intuitive that the soundest course of action was to initiate treatment in the field and rush the victim to the closest ED in hopes of beating the clock; cardiac arrest patients need doctors, and paramedics aren’t doctors, as the thinking went.

EMS professionals and their medical directors have since come to realize that routinely transporting patients who are in cardiac arrest is bad for patients and risky for providers.

High-quality compressions, now known as vital to neurologically intact survival, are difficult to achieve in a moving ambulance. And crews working unrestrained in the patient compartment is dangerous, especially when the driver has that “I’ve got a dying man in the back of my truck and we need a doctor now!” thought process.

Awareness of the problems with the load-and-go strategy for codes led to the “work them where you find them” approach. With the growing consensus that nontraumatic cardiac arrest patients stand their best chance of survival when worked on scene, the next step was to...
determine whether the other code management strategies in place at the time were effective in achieving resuscitation.

The New Era of Resuscitation
In 2005, WCEMSS began implementing new American Heart Association guidelines for compressions, ventilations, and induced hypothermia in cardiac arrest.

Continuous compressions with minimal interruptions and single defibrillations replaced 15:2 ratios and stacked shocks. The use of intraosseous drills allowed for rapid circulatory access. Paramedics de-emphasized early intubation provided that effective ventilation could be maintained through BLS adjuncts or blind insertion airways.

Providers also took great care to avoid hyper-ventilation, utilizing an ITD equipped with timing lights set to proper ventilatory rates.

When to Stop?
WCEMSS demonstrated that these changes to cardiac arrest procedures have a net positive effect on survival rates and greatly increase the absolute number of neurologically favorable outcomes. Had the new approach instead caused a significant climb in the rate of survivors with devastating brain damage, however, the implementations would certainly have been viewed as a failure.

Healthcare professionals generally agree that a person’s quality of life is at least as important as his mere ability to sustain a pulse, and it’s in this context that the questions of resuscitation termination versus prolongation become pertinent.

With the new and effective approach of on-scene resuscitation prior to transport, how long should paramedics continue their efforts and still expect the patient who survives to have a good quality of life? Do lengthy resuscitations contribute to significantly greater rates of comatose and severely disabled survivors?

To answer these questions, WCEMSS collaborated with WakeMed Health and Hospitals and SAS Institute to conduct a retrospective study of out-of-hospital cardiac arrests in the Wake County EMS System from 2005 through 2012.

Overall survival to hospital discharge during the full implementation phase nearly tripled from baseline & critically, neurologically intact survival remained essentially the same.

The final phase of implementation introduced induced hypothermia by EMS following return of spontaneous circulation; WCEMSS has since been initiating hypothermia during the intra-arrest period as well.

The results of these modifications were astounding. Overall survival to hospital discharge during the full implementation phase nearly tripled from baseline and critically, neurologically intact survival remained essentially the same: roughly three quarters of discharged patients had CPCs of 1 or 2.\(^3\)

Working codes on scene with new interventions and improved management strategies, like the choreographed “pit crew” process, was allowing more people in Wake County to live meaningful lives following out-of-hospital cardiac arrest.

No Drawbacks to Extended Efforts
Not surprisingly, the results showed that the longer patients had to be resuscitated, the less likely they were to survive to hospital discharge. Of those patients who did survive prolonged resuscitations, however, many were neurologically intact: The study found that nearly 70% of survivors who were in arrest longer than 40 minutes from the time of dispatch were discharged from the hospital with a CPC of 1 or 2. This rate of neurologically intact survival, in fact, approached the NIS rate for all survivors—83%.\(^4\)

These data demonstrate that meaningful neurological outcomes are not only possible, but in fact probable, in patients who survive cardiac arrest after extended resuscitations. The evidence from this study does not support the concern that those who survive prolonged cardiac arrest will more than likely suffer severe neurological impairment.

Put in real-world terms, the research implications are dramatic. Over the seven years studied...
Beyond the 25-Minute Mark

WCEMSS data demonstrate that meaningful neurological outcomes are not only possible, but in fact probable, in patients who survive cardiac arrest after extended resuscitations.

In Wake County, if providers had strictly limited their efforts to 25 minutes from the time they were dispatched, approximately 100 neurologically intact survivors would have had their resuscitations prematurely abandoned.

The longest duration of arrest that resulted in a patient’s neurologically intact survival was 73 minutes, a case that illustrates the potential for favorable outcomes in codes worked well beyond the standard 25-minute futility mark.

It must be acknowledged that in many cases, 25 minutes of ACLS care is sufficient to determine futility. The victim who has sustained asystole for this duration despite aggressive intervention provides a clear example of someone unlikely to benefit from continued efforts.

In light of WCEMSS’s research, however, EMS providers shouldn’t necessarily feel compelled to cease resuscitation if there remain signs of viability, such as good EtCO₂, or a persistent shockable rhythm.

Further studies will hopefully elucidate which factors predict survivability from prolonged arrest. Until then, paramedics should apply their clinical judgment when considering whether to continue resuscitation beyond 25 minutes.

Conclusion

WCEMSS paramedics continue their attempts to revive the man who collapsed on the side of the road. The team maintains continuous compressions, controlled ventilations and cold fluid infusion, while hanging a procainamide drip and administering additional defibrillations. After 40 minutes of resuscitative efforts and more than a dozen shocks, the patient’s v fib finally breaks, his heart resuming a sinus rhythm, and providers note strong femoral and radial pulses.

Following return of spontaneous circulation, the responding crews remain on scene for 10 minutes to prepare the patient for transport and monitor him closely for re-arrest. He begins to exhibit spontaneous respirations and movement, though remains unresponsive to commands.

The paramedics transport the patient to the ED, where doctors continue EMS-initiated therapeutic hypothermia. The man ultimately receives a cardioverter-defibrillator and is discharged to home neurologically intact.

Cases such as this demonstrate the ability to achieve good neurological outcomes despite extended resuscitative efforts. WCEMSS data indicate that a significant majority of the survivors of lengthy codes are subsequently able to live and function independently.

Providers should continue their efforts undaunted for cardiac arrest patients who don’t meet termination criteria or who show other signs of viability after 25 minutes of resuscitation. Though overall survival from prolonged arrest is poor, those who reach hospital discharge are likely to enjoy a meaningful quality of life.

James Dorroh, EMT-P, is a paramedic with Wake County EMS. He’s also an EMS instructor at Wake Technical Community College, a patient simulation facilitator, and a member of the WCEMS Carolina Hurricanes Medical Team.

Patricia Overman, EMT-P, is a paramedic with Wake County EMS. She’s the former ALS coordinator for Network Ambulance Service in Scranton, Pa. She’s a full-time student at Western Carolina University pursuing her B.S. in emergency medical care. She has more than 20 years of EMS experience in private, public and volunteer agencies.

Benjamin Applebome, EMT-P, is a paramedic with Wake County EMS. He’s also an EMS instructor at Durham Technical Community College.

References

The Memphis Fire Department (MFD) and Richmond (Va.) Ambulance Authority (RAA) have a lot in common. Both services are innovators in EMS, have an enthusiastic staff that continues to implement ways to improve the care they render to their patients and both have been searching for ways to improve their resuscitation success rates.

Each also believes they’ve found that way by implementing mechanical CPR in their agency. MFD uses the Physio-Control LUCAS 2 chest compression system and RAA uses the ZOLL AutoPulse non-invasive cardiac support pump.

Though they’re using different devices, their results have been dramatic and have convinced their medical and administrative leadership that mechanical CPR offers many benefits over manual CPR, not the least of which is the ability to maintain consistent and uninterrupted CPR—a key ingredient in the successful resuscitation and discharge of patients neurologically intact from the receiving hospital.

MFD and RAA are both keenly aware that sudden cardiac arrest (SCA) is a leading cause of death among adults over the age of 40 in the United States, that approximately 424,000 people experience EMS-assessed out-of-hospital nontraumatic SCA annually (more than 1,000/day) and nine out of 10 victims currently die.1

The number of people who die each year from SCA is roughly equivalent to the combined number of people who die from Alzheimer’s disease, assault with firearms, breast cancer, cervical cancer, colorectal cancer, diabetes, HIV, house fires, motor vehicle accidents, prostate cancer and suicides combined.

SCA can be best impacted by early intervention with cardiopulmonary resuscitation (CPR), defibrillation, advanced cardiac life support, therapeutic hypothermia and other measures of comprehensive post-resuscitation care.

When bystanders intervene by providing early, high-quality CPR and using automated external defibrillators (AEDs) before EMS arrives, four out of 10 victims survive.1

This article will detail the path each service has taken to success in implementing mechanical CPR on their frontline ambulances.

The MFD Experience

The MFD, the largest EMS system in the state of Tennessee and the Midsouth, responds to more than 121,000 EMS calls annually. MFD is an all advanced life support (ALS) system that operates 36 ALS ambulances, 56 ALS engines, and 21 BLS ladder truck companies with a staff of 500 firefighter/paramedics and 1,100 firefighter/EMTs. The department operates 98 pieces of fire

Mechanical CPR is producing resuscitation results beyond expectations

By Joseph Holley, MD, FACEP; Joseph P. Ornato, MD, FACP, FACC, FACEP & A.J. Heightman, MPA, EMT-P

In the more typical EMS environment, mechanical CPR devices like the AutoPulse can deliver consistent, high-quality chest compressions over time with minimal interruption in blood flow.

PHOTO COURTESY RICHMOND AMBULANCE AUTHORITY

Consistent Compressions Count!
apparatus that are ALS capable. ALS response times average just over four minutes.

In addition to teaching a paramedic education program, MFD is a certified American Heart Association education center, and the only fire department in the U.S. authorized by the Continuing Education Coordinating Board for Emergency Medical Services to issue their own CEUs.

Operating one of the most progressive EMS systems in the U.S. means utilizing some of the latest treatment protocols and procedures. This includes induced hypothermia and mechanical CPR devices for cardiac arrest patients, continuous positive airway pressure for congestive heart failure patients, and intraosseous infusion for intravenous fluid access.

MFD also has an aggressive ST elevation myocardial infarction (STEMI) program with an average time of 65 minutes from first paramedic contact-to-balloon in a hospital cardiac catheterization lab.

The city of Memphis is in the heart of the cardiovascular disease belt, rating high on the incidences of heart disease and strokes, according to the American Heart Association. In addition, a 1994 study published in the Annals of Emergency Medicine found that the level of bystander CPR was significantly lower for African-Americans in Memphis when compared to whites. In addition, the traditional social morays prevalent in this region result in a large percentage of patients in cardiac arrest being transported.

Focus on Improving SCA Outcomes
Prior to 2012, the MFD initiated several changes to improve patient outcomes for sudden cardiac arrest. MFD first focused on quality CPR with effective compressions. EZ-IO intraosseous infusion drills and King Airways were added in an effort to reduce the times that compressions were being interrupted. Hypothermia treatment was also initiated in the field. Return of spontaneous circulation (ROSC) rates increased, but MFD continued to look for ways to improve patient outcomes.

In 2011, MFD piloted various mechanical CPR devices, examining cost, crew choice, outcomes and support logistics eventually selecting the Physio-Control LUCAS 2.

Initially, MFD budgetary constraints allowed only 18 devices to be purchased. The devices were deployed randomly throughout the city.

During the first year of deployment, no additional changes were made in protocol or procedure. Detailing of medics resulted in use of the product by a large majority of MFD paramedics.

At the completion of the first year, a comparison between those utilizing the mechanical CPR device and those without revealed a large increase in ROSC rates among patients treated with mechanical CPR.

In determining ROSC rates, MFD included all full arrests where CPR was attempted. While some departments have exclusion criteria for ROSC rates, MFD prefers to include all medical and trauma full arrests in order to more accurately gauge performance, including all heart rhythms.

MFD personnel performed CPR on a total of 1,204 patients in 2012, with ROSC occurring in 250 (21%) of those cases. The LUCAS 2 device was used on 114 full arrests, with ROSC occurring in 37 of those cases. This equaled a ROSC rate of 32% on the LUCAS 2 resuscitations, 11% higher than the overall average for the year.

This substantial improvement in patient care prompted an aggressive effort to fully implement the LUCAS 2 device on all MFD ambulances. To do so, the MFD partnered with the Assisi Foundation of Memphis, a foundation that serves nonprofit organizations working to improve Memphis and the Midsouth.

Due to the initial success with LUCAS 2 devices, the Assisi Foundation provided grant funds to outfit the remaining MFD ambulances with the mechanical CPR devices.

In 2013, with all 35 ambulances equipped with the LUCAS 2 device, the overall ROSC rate rose to 31%, a 10% increase over the previous year. MFD personnel performed CPR on a total of 1,134 patients in 2013, with ROSC occurring in 348 (30%) of those cases. However, for those

The Assisi Foundation provided the Memphis Fire Department with grant funds to ensure every MFD ambulance was equipped with a LUCAS 2 mechanical CPR device.
receiving mechanical CPR, the ROSC rate was an astounding 49%!

The devices are now widely hailed by MFD paramedics, who feel the impact of the device has been profound. Cardiac arrest care now seems less stressful and more organized. And clearly the results speak for themselves.

What Makes the Difference
The MFD medical direction, training and quality assurance team believes the difference is resuscitation results and ROSC improvement is a result of the consistency of CPR delivery. Despite having plenty of personnel on scene at cardiac arrests, there was always a lack of consistency between the quality of first responders CPR, frequency of compressor rotation and frequent pauses in CPR.

These pauses often occurred for inventions to be performed, but also occurred due to patient movement to locations more conducive to CPR or transportation to the ED.

Despite CPR feedback after the call, improvements were hard to maintain. Training wasn’t frequent enough.

Knowing that the three most important aspects of high-quality CPR are a compression fraction of 90%, a compression rate of 110, and a compression depth of 2 inches, the MFD found that the LUCAS 2 provided the consistency that their system lacked. At the MFD’s 2014 EMS Star of Life reception, nearly every cardiac arrest survivor present had benefited from the LUCAS 2 device. One woman had actually been successfully resuscitated twice in two months with the device.

And the results continue to drive change; EDs in the Memphis area are now adding mechanical CPR. Cardiologists in Memphis are also now performing cardiac catheterization while the LUCAS 2 device helps maintain a pulse.

The RAA Experience
The Richmond Ambulance Authority (RAA) is a high-performance EMS system that’s well-known for technological innovation, operational efficiency and research focusing on CPR, field management of major traumatic injury and safety.

Richmond Fire & EMS provides primary first response and automated external defibrillator care and RAA functions as the sole, all-ALS ambulance provider in the city of Richmond. Fire crews are positioned conventionally in fire stations while RAA’s ALS ambulances are positioned dynamically 24/7 throughout the city using advanced system status management (SSM) that bases the unit placement on data analysis of where the most likely next life-threatening call will occur.

The SSM strategy, refined by more than 24 years of experience, is extraordinarily effective, resulting in an ALS-response time interval to scene consistently greater than 90% in all sectors of the city in 8 minutes, 59 seconds or less.

In 2004, RAA added ZOLL AutoPulse load-distributing band chest compression devices on all of its ALS ambulances. The RAA protocol calls for early application of the device during resuscitation when there’s still maximum patient viability.

RAA has found that the primary advantage of the device is that it provides consistent, high-quality, minimally interrupted chest compressions that can be maintained during defibrillation and, on rare occasions when required, during patient transport. It can be applied quickly by a well-trained crew.

In a before/after implementation of mechanical chest compression comparison, RAA demonstrated a significantly improved survival to hospital discharge. However, RAA was cautious to point out that, in its “control period” prior to deploying the mechanical device in 2004, the quality of manual CPR being performed was highly variable. Thus, RAA hypothesized that much of the improvement seen in survival might represent the difference between not-so-well-performed manual CPR (as was the case in most EMS systems and hospitals prior to 2004) vs. consistent, high-quality, mechanical chest compression.

This hypothesis has proven to be well-founded. In a follow-up clinical trial, 522 randomized out-of-hospital cardiac arrest patients in three U.S. and two European sites compared high-quality manual CPR using real-time feedback vs. load-distributing band chest compression with the AutoPulse device. Sustained ROSC, 24-hour survival and survival to hospital discharge were statistically equivalent. The 20-minute CPR fraction (the % of time each minute that chest compressions were being performed) in the trial was excellent in both groups (80.4% for AutoPulse and 80.2% for manual CPR).

Clinically Proven
The RAA conclusion is that mechanical chest compression with devices such as the AutoPulse can at least equal survival outcomes seen with optimally-performed CPR in a clinical trial setting with highly trained crews using real-time quality of CPR feedback devices. However, in
the more typical EMS environment, mechanical CPR devices can deliver consistent, high-quality chest compressions over time with minimal interruption in blood flow.

In addition, these devices lessen the physical exhaustion that can occur when manual CPR needs to be sustained for more than a few minutes, and allow rescuers to focus their attention on other important tasks during resuscitation.

Joseph Holley, MD, is medical director of the Memphis Fire Department, as well as numerous EMS agencies in the region, a member of the Metropolitan Medical Directors (Eagles) Coalition, and the EMS medical director for the state of Tennessee. He can be contacted at Joe.Holley@memphistn.gov.

Joseph P. Ornato, MD, is medical director of the Richmond Ambulance Authority, Richmond Fire & EMS, and Henrico County Division of Fire, and is a member of the Metropolitan Medical Directors (Eagles) Coalition. He may be contacted at ornato@aol.com.

R.J. Frascone, MD, FACEP, demonstrates the LUCAS 2 device following a spectacular save where a man received more than 2 hours, 45 minutes of mechanical CPR.

References
Advances in Resuscitation

Dramatic Mechanical CPR Saves

Mike Snyder’s parents were worried about the safety of their son, Jordan, 24, while he was serving in Afghanistan. Little did they know that it would be Mike, their 27-year-old son living nearby in Richmond, Va., who would be the one at death’s door.

His brush with death happened on a cold December night when Mike, his wife, Jen, her brother, Justin, his girlfriend, and two cousins returned to Justin’s apartment after the group had spent the evening at a movie followed by a late dinner. Mike said he didn’t feel well, so Jen went to get him a glass of water. By the time she arrived back at his side, Mike had collapsed and wasn’t responding. Justin immediately called 9-1-1 while his cousin Caleb initiated CPR, setting the chain of survival into motion.

With the Richmond Ambulance Authority (RAA) on the line, the family and friends put the phone on speaker so they could hear instructions from dispatcher Travis Gortney. It was Gortney’s first cardiac arrest; he had joined RAA just four months earlier.

Firefighters from Richmond’s Quint 18 were the first to arrive and continued CPR until the paramedics arrived. RAA paramedic Alex Klimenko arrived with his EMT partner Jonathan Carroll, grabbed all of their equipment—including the ZOLL AutoPulse non-invasive cardiac support pump, which is part of their protocol—and ran up three flights of stairs to the apartment.

Finding Mike collapsed in the doorway to a bathroom in complete arrest, they quickly placed him on the AutoPulse for continuous, consistent chest compressions. In addition to compressions from the AutoPulse, Mike received seven defibrillating shocks.

“By this time, Mike had been in sudden cardiac arrest for 30 minutes, and we had worked on him for 20, using everything we had, including medication and therapeutic hypothermia,” Klimenko said.

After several minutes of resuscitative efforts, Snyder responded to the care and his heart converted to a stable rhythm with pulses returned. As the firefighter and ALS crew was placing Snyder on an evacuation stretcher, with the AutoPulse still in place, he lapsed back into cardiac arrest, so they reactivated the AutoPulse as they continued downstairs and to the awaiting ambulance.

“Since we had the AutoPulse, we could carry him down the three flights of stairs while it continued chest compressions. Without the AutoPulse, getting him down those stairs would have been 10 times more difficult,” Klimenko said. “It continued perfusion to his brain and delivered quality chest compressions, something we wouldn’t have been able to provide without the device.”

Klimenko adds, “Without the AutoPulse, we feel the outcome would have been different. The device makes an incredible difference, which is why we kept it on him during the 12-minute lights-and-siren drive to Virginia Commonwealth University (VCU) Hospital.”

At VCU, Mike was transferred over to the ED staff. Although he regained a pulse, Mike remained unconscious, so he was moved to the VCU advanced resuscitation, cooling therapies and intensive care (ARCTIC) unit where he was cooled to 33 degrees C.

After 24 hours, the ARCTIC team slowly began rewarming Mike’s cooled body and provided intensive support to ensure his ultimate recovery. He regained consciousness and was released with the ZOLL LifeVest wearable defibrillator, which monitors the heart 24/7.

Mike wore the LifeVest for a month until undergoing an open heart ablation procedure at VCU to correct the rogue pathway that caused his arrest. Mike was diagnosed with Wolff-Parkinson-White syndrome, an abnormal electrical pathway that can cause palpitations, dizziness and other symptoms, when he was young, after his dentist identified it as a possibility. Although rare, WPW can also cause sudden cardiac arrest. Until his near-death experience, Mike had been asymptomatic for years.

RAA has been using the AutoPulse since 2005 and has seen a significant increase in the number of patients who obtain return of spontaneous circulation (ROSC). Klimenko says, “The AutoPulse is easy to apply and use. It takes us under a minute to deploy.”

One year to the day later, Mike, Jen and their little daughter, Lily, 2½, returned to RAA, to meet and thank the rescuers who gave him a second chance at life. Mike is glad for the second chance. He told his rescuers that he was very appreciative of their fast response and care, stating, “They gave me back my life. The odds of me waking up alive and as the same person mentally and physically were so extraordinarily low. It’s just amazing. You can’t put a price on that. I get to see the sunrise every day and see my daughter smile. And I’m forever grateful to ZOLL and the team at RAA who saved my life.”

Mike Snyder (center) poses with paramedic Alex Klimenko (left) and EMT Jonathan Carroll.

PHOTO COURTESY RICHMOND AMBULANCE AUTHORITY


**Dramatic Mechanical CPR Saves**

Too Unstable to Fly

During most of the year, the population of West Yellowstone, Mont., is around 1,000 people. But during the summer, up to 15,000 visitors stream into Yellowstone National Park every day through the popular entrance near Old Faithful. And, when tourism soars, so do calls for emergency services and medical care.

The Hebgen Basin Fire District (HBFD) serves this 300-square-mile area of rugged terrain in the Gallatin National Forest of Montana’s Southwest Rockies. During peak season, it’s not unusual to receive multiple calls at the same time for ambulances.

Unlike more densely populated areas, the closest hospital is 84 miles away in Rexburg, Idaho. And the closest cardiac and trauma center is 110 miles in Idaho Falls.

When 56-year-old local hotel maintenance worker Steve Bartlett experienced chest pains and difficulty breathing, and then lapsed into sudden cardiac arrest (SCA), he was fortunate that an HBFD ambulance equipped with a Zoll AutoPulse non-invasive cardiac support pump responded to the 9-1-1 call to assist him.

Within minutes of the 9-1-1 call, Captain John Moore and his partner, Leslie McBirnie, arrived at Bartlett’s side in the maintenance shop.

“He was talking with us and had the look of a very sick person,” says McBirnie. “I went to get the stretcher and when I came back inside, Moore told me that Steve just had a seizure and was unconscious. We moved Steve to our ambulance. He still had a pulse. But, about a minute later, he went into sudden cardiac arrest.”

McBirnie immediately started manual chest compressions, while Moore grabbed the defibrillator and shocked Bartlett. It would be the first of many times that evening that Bartlett would be shocked.

They then placed the ZOLL AutoPulse on and began to deliver consistent, high-quality automated chest compressions to Bartlett. Soon after the AutoPulse was put into operation, Bartlett achieved return of spontaneous circulation (ROSC). The AutoPulse was turned off, but left in place. Minutes later, Bartlett rearrested and the AutoPulse was turned on again for four minutes. The HBFD crew then realized that a clinical pattern was developing.

Bartlett’s pulse was between 60 and 70 beats per minute, but it couldn’t be maintained. He next went into v tach, was shocked and converted into a sinus rhythm with frequent premature ventricular contractions. His pulse then dropped below 40 and the AutoPulse was once again turned on for another round of mechanical chest compressions.

A decision was then made to call Air Idaho to have Bartlett flown to the catheterization lab at Eastern Idaho Regional Medical Center in Idaho Falls.

Moore and McBirnie transported Bartlett to a designated landing zone to meet to meet the Air Idaho flight crew, with the AutoPulse still operating.

Following a 20-minute drive to the landing zone, the ground and air crews agreed Bartlett was too unstable for the flight, so the flight crew joined Moore and McBirnie in the ambulance and they transported Bartlett to the town of St. Anthony, the halfway point between the landing zone and Idaho Falls, where they met an Idaho Falls Fire department (IFFD) ambulance.

At the hospital, Bartlett coded 30 times the first night in the ICU, then another 15 times the second night. He spent three weeks in the hospital and eventually underwent surgery to have a stent inserted.

Bartlett recovered with no neurological deficits and returned to a HBFD Board of Directors meeting to thank Moore, McBirnie and what he called “that good-looking machine” (i.e., the AutoPulse) that helped to save his life.

Asked what role the AutoPulse played when Bartlett collapsed, Moore didn’t hesitate in his reply. “It saved his life,” Moore said. “The first time we activated it on Bartlett, he had ROSC. In later attempts, we were able to once again achieve ROSC. The AutoPulse worked flawlessly, doing what it was designed to do every time we activated it.”
Dramatic Mechanical CPR Saves

Savin' in Memphis

31 Delta 2—Unresponsive Patient
Early in the morning on Aug. 1, 2014, 67-year-old Joyce Wynn was walking with her friend and suddenly collapsed. The call to 9-1-1 came at 5:22 a.m. for an unresponsive patient and Memphis Fire Department (MFD) Engine 48 and ALS Unit 13 were dispatched.

Dispatchers advised the units that a nurse was on the scene and had initiated CPR. On arrival, Engine 48 assumed patient care, continued CPR and began treatment. ALS Unit 13 arrived and deployed the LUCAS 2 chest compression system to ensure quality CPR.

The patient was intubated, shocked and medicated, and she soon spontaneously regained a pulse. Induced hypothermia protocols were initiated and Wynn was transported to Methodist North where she had begun to breathe on her own by the time she arrived.

Wynn was treated at Methodist North and was discharged with no deficit.

9 Echo 1—Patient Not Breathing
At 6:30 a.m. on Oct. 20, 2013, 53-year-old Pamela Greer collapsed in her living room. The 9-1-1 operator received the call at 6:34 a.m. and immediately dispatched MFD Engine 30, ALS Unit 34 and EMS Lieutenant 204.

The 9-1-1 operator began pre-arrival and CPR instructions. The family was scared and under duress, but followed directions to the best of their ability. On arrival, Engine 30 and ALS Unit 34 assumed patient care, continued CPR and initiated treatment. ALS Unit 34 rapidly deployed the LUCAS 2 and the patient was intubated, shocked and given cardiac drugs. Induced hypothermia protocols were initiated, 12 lead ECGs were transmitted to St. Francis Park Chest Pain Center and, while en route, the patient spontaneously regained a pulse, began fighting the ET tube and breathing on her own.

Greer was treated and discharged without any deficits.

33 Delta 1—Sudden Cardiac Arrest at a Dialysis Clinic
At 1 p.m. on April 4, 2014, 58-year-old Joe Euell was receiving his dialysis treatment when he suddenly went into cardiac arrest. The nurses and staff immediately began CPR and applied an AED which delivered two shocks.

Treatment continued while the 9-1-1 system was activated. MFD Engine 11, ALS Unit 12 and EMS Lieutenant 202 were dispatched and, on arrival, assumed patient care, continued CPR and initiated treatment including early, rapid application of the LUCAS 2. The patient was intubated, shocked and cardiac drugs were administered.

While on scene the patient had a return of spontaneous circulation and began to attempt to breathe. Induced hypothermia protocols were initiated in the field and Euell was transported to Methodist University, where he was treated and discharged with no deficits.

9 Echo 1—Cardiac Arrest
On Sept. 15, 2013, at approximately 11:50 p.m., 57-year-old Edmond Leone collapsed in front of his wife and stopped breathing. The call to 9-1-1 came at 11:54 p.m. and MFD Engine 59 and ALS Unit 30 were immediately dispatched. They arrived to find the patient’s wife performing CPR.

The LUCAS 2 was rapidly deployed to ensure effective, high-quality CPR, the patient was intubated, shocked and had cardiac drugs administered. Induced hypothermia protocols were also initiated and, before transport to the hospital, the patient’s cardiac rhythm stabilized and regained a pulse.

Leone was transported to St. Francis Bartlett Hospital and was ultimately discharged with no deficits.

10 Delta 4—Severe Chest Pain
On Jan. 1, 2014, just after midnight, 54-year-old Edward Martin began complaining of a sudden onset of severe chest pain. His wife immediately called 9-1-1 and was given pre-arrival instructions. MFD Engine 54 and ALS Unit 18 were dispatched and arrived to find Martin in a very unstable condition: short of breath, diaphoretic and complaining of severe chest pain. They initiated IV and cardiac medication, and obtained, interpreted and transmitted a 12-lead ECG to Baptist Memphis Hospital’s ED—all in just 7 minutes!

During transport, Martin’s condition continued to deteriorate and, as ALS Unit 18 was pulling into the ambulance bay at Baptist Memphis, he went into v fib. The crew immediately shocked him and started the LUCAS 2, which helped the crew—now without the additional engine company personnel—to administer uninterrupted compressions as they worked to resuscitate the patient.

Martin regained a pulse as he was wheeled into the ED. He received definitive treatment in the ED and catheterization lab and survived without deficit.

The LUCAS 2 chest compression system has aided the Memphis Fire Department in delivering high-quality CPR during numerous saves.
Thousands of EMS professionals rely on the Red Cross to be ready to respond.

The Red Cross delivers premier curriculum and resources in resuscitation education. And going beyond our current suite of certification programs, we are expanding our trusted portfolio to help drive better patient outcomes for the EMS community.

From Emergency Medical Response to Basic Life Support, the Red Cross is the right choice for your training needs.

Find out more: redcross.org/bls

Breathing new life into EMS learning and development.
How coordinated “pit crew” procedures have helped improve cardiac arrest resuscitations in the field

In auto racing, seconds can make the difference in winning or losing a race. NASCAR teams have proven the effectiveness of what’s referred to as the “pit crew” approach to rapid, coordinated, race car pit maintenance stops to avoid unnecessary delays, get critically important tasks completed in the minimum amount of time and avoid errors that can cost them time and, ultimately, the race.

In the race to save cardiac arrest patients, it’s now also been shown that the use of a “pit crew” approach by EMS crews can also make resuscitations more effective by reducing interruptions in compressions and peri-shock pauses, reducing delays in interpreting cardiac activity, eliminating pauses for airway management and reducing the time it takes to place and activate mechanical CPR devices.

This article focuses on three progressive EMS systems that have each been highly effective in standardizing their approach to cardiac arrest resuscitation by implementing the pit crew approach to resuscitation, using well-defined process and clinical procedure checklists and other methods to limit delays in the care and resuscitation of patients.

**Wichita-Sedgwick County, (Kan.) EMS:** Sabina Braithwaite, MD, MPH; Jon E. Friesen, MS, EMT-P; Scott Hadley, MBA, BSN, RN, EMT-P & Darrel Kohls, BA, EMT-P

**Austin-Travis County (Texas) EMS:** Paul R. Hinchey, MD, MBA, FACEP; Michael Prather, EMT-P & Mark Karonika, EMT-P, FP-C

**Wake County (N.C.) EMS:** Brent Myers, MD, MPH, FACEP; William D. Holland II, BS, M.Div, EMT-P; Candice M. Eason, AAS, EMT-P & Justin Carhart, AAS, EMT-P

In 2012, the Wichita-Sedgwick County, Kan., EMS System (W-SCEMSS) modified the Austin-Travis County (Texas) EMS pit crew approach to resuscitation of cardiac arrest patients to meet the needs of the local system. The goal was to not only produce a more consistent resuscitation team and a well-choreographed approach to resuscitation but to also produce
better results from resuscitations, increasing the number of return of spontaneous circulation (ROSC) patients and patients who leave the hospital neurologically intact.

The pit crew model designs structure, consistency, efficiency and accountability into our approach to resuscitation.

W-SCEMSS took the basic Austin-Travis County design that had defined roles and responsibilities for each team member and the “sacred BLS triangle,” and made it its own by having its EMS providers refine it to be workable in the Wichita-Sedgwick County system. (See Figure 1.)

Among other things, W-SCEMSS made a decision to have very specific equipment placement. For example, the cardiac monitor is specified to be placed so the rhythm and end-tidal carbon dioxide (EtCO₂) information on the monitor can be seen immediately by more than one ALS provider and the BLS pit crew. This ensures that paramedic consensus regarding the rhythm occurs with minimum delay and without lengthening the CPR pause if there’s any question. It also provides real-time feedback regarding compression effectiveness and the potential ROSC to the entire team.

W-SCEMSS also chose to choreograph all actions to the number of compressions in a cycle rather than having crews try to watch a clock to keep time. With a metronome set at 110/minute, the cycles are 220 compressions rather than two minutes. Every 20 count is called out by the person in the airway position of the resuscitation team so the rest of the team knows when to perform other actions that are required at a specific time during the cycle.

Given the economy in recent years, W-SCEMSS has limited resources for quality improvement. Therefore, the choice of what would be monitored and evaluated needed to be very deliberate and focused so the medical director and clinical coordinators would know if the system was producing better results.

Traditionally, metrics such as response time have gotten a great deal of play in the EMS industry as worthy of measurement, mainly because they were relatively easy to measure. But in recent years, studies have shown that the time to get to the patient’s side likely plays much less of a role than what happens once the provider encounters the patient.¹ ²

W-SCEMSS’ first step in deciding on what metrics were worth measuring was to make a decision on what the most important endpoints to reach were. The ultimate goal was not only to deliver more pulsatile patients to EDs, but to also have more patients leave the hospital neurologically intact.

Because W-SCEMSS participates in the national Cardiac Arrest Registry to Enhance Survival (CARES), with its linkages to hospital outcomes and utilizing standardized definitions, the method of monitoring progress in achieving this ultimate goal and comparing to EMS agencies nationally was already in place.³ ⁴

---

**Figure 1.**

W-SCEMSS pit crew procedure

---

[Image of W-SCEMSS pit crew procedure]
W-SCEMSS chose to monitor the impact of the pit crew approach in two areas and within several time frames:

Area #1
First, how was the system complying with the simple targets set for each individual patient resuscitation based on the best currently available practices and evidence? The three items identified as most important were:
1. Minimal CPR interruptions (target less than 10 seconds);
2. Compression rate of at least 100/minute (including pauses), with CPR ratio of > 95% and compression ratio of ≥ 90%; and
3. Right-timed defibrillation (with minimal interruption, see #1).
These were encouraged in our pit crew model by the following processes and procedures:
1. Joint education sessions for all providers on the critical importance of limiting compression pauses;
2. Use of metronomes at 110/minute; and
3. Charging the defibrillator prior to each 220 compression pause for rhythm check to limit additional delay for charging.

Area #2
The W-SCEMSS team also felt it important to provide prompt feedback on individual performance to all providers caring for a patient, so self-motivated behavior modification could take place without further supervisory intervention. This was done by annotating each cardiac arrest (preferably within 72 hours) and providing the documentation to the crews and their supervisors.

Pause duration was specifically noted, as was CPR ratio, compression ratio, compression rate and compressions/minute.

Initial data was very encouraging, with targets being met. However, after about three to four months, system administrators noted a pronounced drop-off in compliance, with pause lengths creeping up over 30 seconds and compression ratios down from > 90% to 80%.

At this point, the system didn’t have enough patient data to prove that the changes that had been made were making a difference overall in neurologically intact survival to discharge. It would take at least nine to 12 months to potentially show a positive trend. But it was clear the system needed to reengineer its pit crew approach by creating simple process changes to develop a default path that would produce the desired result.

To meet the three targets outlined in Area #1, it was clear the primary issue to address was the length of any pauses occurring between cycles. To do this, W-SCEMSS made three process changes:

1. The entire team is programmed to know that compressions are to restart after 16 metronome beats (8.7 seconds) of interrupted CPR. To ensure this process compliance, the team verbally counts metronome beeps during any pause in compressions. Because the metronomes are set at a rate of 110/minute, the audible count allows the crew to get their hands back on the chest at the 16th beat of the interruption interval and, by default, keeps pauses under the 10-second goal each cycle. The code commander can ask for a longer pause, but the default is a measured pause that’s less than 10 seconds or 16 metronome beats;

2. The code commander keeps their fingers on the patient’s femoral pulse—starting at the 180th compression during each cycle—to monitor quality of CPR and know immediately if there’s any organized rhythm noted on the monitor that’s actually producing

Table 1: Impact of pit crew approach on resuscitations in Wichita-Sedgwick County, Kan.

<table>
<thead>
<tr>
<th></th>
<th>12-month period before pit crew process initiated (6/1/11–5/31/12)</th>
<th>12-month period after pit crew process initiated (6/1/13–5/31/14)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sustained return of spontaneous circulation in the field</td>
<td>Sustained return of spontaneous circulation in the field</td>
</tr>
<tr>
<td></td>
<td>Proportion of survivors neurologically intact</td>
<td>Proportion of survivors neurologically intact</td>
</tr>
<tr>
<td>All rhythms¹</td>
<td>10.3% (34 of 329 patients)</td>
<td>29.2% (96 of 328 patients)</td>
</tr>
<tr>
<td></td>
<td>66.7% (34 of 50 patients)</td>
<td>91.4% (43 of 47 patients)</td>
</tr>
<tr>
<td>Bystander-witnessed</td>
<td>18.1% (21 of 116 patients)</td>
<td>42.6% (43 of 101 patients)</td>
</tr>
<tr>
<td>arrests only</td>
<td>66.7% (24 of 36 patients)</td>
<td>95.6% (22 of 23 patients)</td>
</tr>
</tbody>
</table>

¹. CARES data for bystander-witnessed, EMS-witnessed and unwitnessed.
Three Successful EMS Systems

a pulse when CPR is stopped. This eliminates the need for someone to search for the pulse location, since it has already been confirmed during CPR; and

3. The defibrillator is pre-charged beginning at the 200 count in each cycle—20 compressions before hitting the 220 mark. In this manner, as soon as CPR stops, the patient can be shocked immediately if a shockable rhythm is identified. This keeps the pause shorter and also limits the peri-shock pause; longer peri-shock pauses have been shown to decrease survival.5,6

By limiting pauses with these interventions, compression ratios came back up to the desired targets. These changes in pit crew choreography have resulted in significantly decreasing pauses and getting them back into the target range, and W-SCEMSS now consistently shows compression ratios of > 90%.

Looking at the big picture, the overall W-SCEMSS survival for the year after full pit crew implementation was 13.7% (compared to a national average of 9.4%), an Utstein survival of 48.6% (28.9% national average) and, of survivors who made it to discharge, 91.4% were neurologically intact with cerebral performance scores of 1 or 2 (79.6% national average).

Implementation of the W-SCEMSS cardiac arrest initiative has been rewarding in other ways also. Neurologically intact survivors have returned to thank providers, and there’s no reward greater than that!

None of our success would’ve been possible without everyone in the system being open to learning and implementing a radical change in how we approach resuscitation, and each resuscitation team fully embracing the new practice pattern, supported by complete management buy-in.

Austin-Travis County, Texas

Many argue that running a cardiac arrest isn’t intellectually or clinically challenging and so they dismiss its complexity. Successful management of cardiac arrest, however, is far more difficult than we believe. What makes consistently well-run codes so elusive is the competing needs of various interventions, the need for constant attention in a chaotic environment, and our inherently poor perception of task time. Choreographed or pit crew CPR is a great example of EMS innovation and process engineering designed to address these challenges and those of the prehospital environment.

What has made choreographed CPR invaluable to Austin-Travis County and other systems across the outcome spectrum is the consistency it brings. Before utilizing the pit crew approach, every cardiac arrest was carried out in a different manner, adding to the variability of cardiac arrest management and making it difficult to define and describe. Now every cardiac arrest is engineered to be the same.

Like Wichita-Sedgwick County and Wake County (N.C.), Austin-Travis County uses a uniform process that allows us to better isolate and measure elements of cardiac arrest management. Over the last four years of pit crew, that consistency has contributed to improvement in our outcome measurement, feedback to providers, compression quality, timing of interventions and bystander CPR and AED availability initiatives.

Leadership, a standardized approach and constant review have contributed to success in Austin-Travis County.

### Table 2: Impact of pit crew approach on resuscitations in Austin-Travis County, Texas

<table>
<thead>
<tr>
<th></th>
<th>12-month period (1/1/13–12/31/13)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sustained return of spontaneous circulation in the field</td>
</tr>
<tr>
<td>All rhythms1</td>
<td>33.8% (179 of 530 patients)</td>
</tr>
<tr>
<td>Bystander-witnessed arrests only</td>
<td>48.2% (119 of 247 patients)</td>
</tr>
</tbody>
</table>

1. CARES data for bystander-witnessed, EMS-witnessed and unwitnessed.
These represent the easily quantified benefits of choreographed CPR. But, like other EMS systems that have implemented the pit crew approach, we’ve found it improves far more than just the numbers. The following comments on the impact of pit crew are from system providers at different agencies. Their comments were provided independently without any input or knowledge of the others’ content.

Battalion Chief Michael Prather, EMT-P, of Lake Travis (Texas) Fire Rescue: When Lake Travis Fire Rescue adopted the pit crew model of CPR, it was a change to the standard American Heart Association training for cardiac arrest.

I’d been doing it for years. After training to use the pit crew approach, I quickly realized it made perfect sense.

As firefighters on an engine company, we all have a designated assignment for a house fire. We know before arriving on scene that one firefighter is going to grab an attack line; the other firefighter is going to force entry to the house; the officer will do a 360 of the incident to look for hazards and formulate a plan; and the engineer will get the engine ready to supply water. So, why would we treat cardiac arrest differently?

The pit crew model allows personnel to know what their assignments are before we even walk through the front door.

The importance of a story
By Paul R. Hinchey, MD, MBA, FACEP

The stories that live in any profession or organization are an important reflection of what that group values.

If your folklore is about a paramedic intubating upside down in a car, at night, with a shoehorn, during a hurricane, your system probably values skills. If it’s a story about a provider making a sandwich for a diabetic or taking a gift to a sick child in the hospital, caring and compassion are important to you.

I like stories highlighting EMS providers that know and apply the science of prehospital medicine instead of following protocols without understanding why. This is one from a couple of years ago in the Austin-Travis County EMS system that illustrates this point.

A patient in his 50s suffers a cardiac arrest at home. Bystanders are given CPR instructions by phone and begin compressions just minutes after the collapse. Fire first responders arrive, begin choreographed CPR and deliver several shocks. EMS arrives and the cardiac arrest continues for another 40 minutes with a dozen defibrillations and two double-sequential defibrillations that finally result in ROSC.

Post resuscitation care is started, including assuring an adequate airway, a 12-lead to confirm no ST elevation myocardial infarction and cold saline for hypothermia is administered. The patient is obviously sick, so firefighters accompany the EMS crew to help if needed. Minutes into the transport the patient rears and the ambulance pulls to the side of the road.

Fortunately we’ve never had to repeat the resuscitation “bail-out” intervention. However, using the same science, we’ve pulled our ambulances to the side of the road to initiate CPR, worked cardiac arrests in the hospital ambulance bay or side-by-side with an ED physician when a patient is pulled from a vehicle at the hospital’s front door.

Prehospital practitioners know what matters in cardiac arrest and that understanding, like the implementation of continuous positive airway pressure, induced hypothermia and end-tidal carbon dioxide, is beginning to influence the management of cardiac arrest both inside and out of the hospital.

But that’s another story.
Three Successful EMS Systems

A firefighter is positioned at each side of the patient filling the assignment of compressor giving 100–110 compressions a minute. They stay in cadence with the metronome and limit pauses during compressions.

The firefighter at the head maintains a mask seal or places an airway, while the person not compressing the chest ventilates the patient.

Initially we were skeptical of the pit crew model. However, after working several cardiac arrests and realizing that the codes ran smoother, everyone accepted the new approach. We all have an assignment that we’re all well-trained to manage. Those assignments allow us to work as a team, just like we would at a fire.

Once the medic unit arrives on scene, they have their assigned positions as well. We integrate additional providers and interventions without interruption of chest compressions or ventilations: we all become one team.

Commander Mark Karonika, EMT-P, FP-C; Austin-Travis County EMS: When we rolled out pit crew, we believed we were already managing cardiac arrest calls at a very high level. How could this improve it?

As a supervisor I respond to every cardiac arrest while on duty, and I have seen the difference this new approach makes. Today I can respond to any cardiac arrest with any first responder or EMS crew in our system and what I will see is the same.

The defibrillator charges, but no one stops what they’re doing until the last possible second. They know we need to keep CPR going to reduce the time off chest until the rhythm and pulse check.

Without being asked or told, compressions start again with a new compressor; a constant focus on high-quality CPR. I see the crews working to solve the problem, and thinking out loud. Any idea is welcome and everyone participates.

This leaves me time to attend to the family to explain what’s happening and care for everyone at the scene.

Our pit crew approach means we run a better and more consistent cardiac arrest but it has changed more than just that. It has changed our relationship with the first responders and fire departments. Now everyone has a role and is equally important to the outcome. Regardless of how you responded to the scene, or what your level of certification, we’re a team.

Wake County, N.C.

Over the past six years, the Wake County EMS System (WCEMSS) has used the pit crew approach to cardiac arrest management which has resulted in an increase of neurologically intact survivors. Each provider has a specific role aimed at the return of spontaneous circulation and neurological survivability.

WCEMSS has enough resources to dedicate a minimum of three ALS response units to every cardiac arrest so that quality care may be delivered on scene. This typically includes two ambulances, a district chief (DC) and/or an advanced practice paramedic (APP). In addition to these, each arrest will have one or more dedicated engine companies from a local fire department.

![Figure 2. Lake Travis Fire Rescue pit crew assignment board](image)

Table 3: Impact of pit crew approach on resuscitations in Wake County, N.C.

<table>
<thead>
<tr>
<th>Wake County, N.C.</th>
<th>12-month period (1/1/13–12/31/13)</th>
<th>Proportion of survivors neurologically intact</th>
</tr>
</thead>
<tbody>
<tr>
<td>All rhythms¹</td>
<td>41.9% (194 of 463 patients)</td>
<td>91.3% (63 of 69 patients)</td>
</tr>
<tr>
<td></td>
<td>95% CI 37–46%</td>
<td>95% CI 82–96%</td>
</tr>
<tr>
<td>ROSC (all witnessed rhythms)</td>
<td>57.4% (97 of 169 patients)</td>
<td>94.9% (37 of 39 patients)</td>
</tr>
<tr>
<td>Bystander-witnessed arrests only</td>
<td>68.4% (39 of 57 patients)</td>
<td>100.0% (26 of 26 patients)</td>
</tr>
<tr>
<td></td>
<td>95% CI 55–79%</td>
<td></td>
</tr>
</tbody>
</table>

¹. CARES data for bystander-witnessed, EMS-witnessed and unwitnessed.
². CI = Confidence interval. This means the data shows that the EMS system can be 95% confident that treatment of the same number of patients in the future will result in the same percental range of results.
In addition to supplying cold fluids, the DCs and APPs also fill a vital role in helping accomplish the systems goals of compassionate and clinically excellent care. By working with the patient’s family and loved ones, the DC or APP act as a liaison between the code commander and family.

Due to the emotionally traumatic nature of many cardiac arrests, DCs and APPs invite the family to observe the resuscitation efforts. By presenting the family with the facts of the resuscitation, they can assist them in making sound decisions regarding their loved one’s care. Families are encouraged to ask questions and understand each intervention of the resuscitation in an attempt to help them cope with the arrest and its ultimate outcome.

When utilizing the team approach, WCEMSS has discovered that it may be necessary to continue beyond the 30 minutes commonly recognized for resuscitation attempts. WCEMSS has demonstrated that patients 60 minutes or longer into an arrest may still have the possibility of surviving neurologically intact. (See “Reuscitating Beyond the 25-Minute Mark: Good neurological outcomes are likely in survivors of prolonged resuscitations,” p. 16.)

Despite each responder having a defined role, prior to terminating resuscitation efforts, the code commander uses the collaborative knowledge of the personnel on scene, which is especially valuable in rare extended resuscitations.

The results in Wake County have been significant with WCEMSS numbers for all cardiac arrests tracked in our CARES report (all rhythms, all codes that were witnessed, unwitnessed, or EMS-witnessed) exhibiting 42% sustained ROSC (194 of 463 patients) and 91% of WCEMSS has developed a great working relationship with the local fire departments and other first responder agencies. Fire personnel primarily concentrate on continuous compressions, bag-valve mask ventilations and early AED defibrillation prior to EMS arrival. They’re essential members of the resuscitation team and are integrated from dispatch to ED transport.

Cardiac arrest resuscitation in Wake County is a well-organized delegation of responsibilities among personnel. Everything possible is done to ensure three paramedics are on scene to assume the responsibilities of code commander, airway management and IV/intraosseous establishment with medication administration. The code commander is the keystone to this team approach.

The code commander focuses on the overall resuscitation, with their primary focus being on the ECG monitor. This ensures that any rhythm changes are quickly identified and addressed. The code commander also oversees the overall pace and timing of critical interventions such as medication administration, two-minute rhythm checks, ventilation rate and compression rate aided by a metronome.

Per protocol, the code commander uses the cardiac arrest checklist, which is a valuable tool for both pre- and post-ROSC. This checklist encompasses all the necessary components of a successful resuscitation and is an important part of delivering the same standard of care to all patients. (See online bonus content at www.jems.com/wake-checklist.)

The most recognizable innovation to Wake County’s cardiac arrest management has been intra-arrest induced hypothermia. This critical intervention for neurological survival has been integrated into the resuscitation through the DCs and APPs who bring cold saline to the arrest.7

It’s imperative to the success of this intervention that receiving hospitals participate. WCEMSS has coordinated with multiple area EDs across multiple hospital systems to ensure cooling is continued.

Everything possible is done to ensure three paramedics are on scene to assume the responsibilities of code commander, airway management and IV/intraosseous establishment with medication administration. The code commander is the keystone to this team approach.

When utilizing the team approach, WCEMSS has discovered that it may be necessary to continue beyond the 30 minutes commonly recognized for resuscitation attempts. WCEMSS has demonstrated that patients 60 minutes or longer into an arrest may still have the possibility of surviving neurologically intact. (See “Reuscitating Beyond the 25-Minute Mark: Good neurological outcomes are likely in survivors of prolonged resuscitations,” p. 16.)

Despite each responder having a defined role, prior to terminating resuscitation efforts, the code commander uses the collaborative knowledge of the personnel on scene, which is especially valuable in rare extended resuscitations.

The results in Wake County have been significant with WCEMSS numbers for all cardiac arrests tracked in our CARES report (all rhythms, all codes that were witnessed, unwitnessed, or EMS-witnessed) exhibiting 42% sustained ROSC (194 of 463 patients) and 91% of
all survivors are neurologically intact on discharge (63 of 69 patients).

For total bystander-witnessed arrests (all rhythms) our ROSC was 58% (97 of 169 patients), with a 95% confidence interval (CI) of 50–65%. And, for witnessed, shockable rhythms, our sustained ROSC using our pit crew approach and treatment modalities was 68% (39 of 57 patients), with 95% CI 55–79% and discharged alive 26 of 57 patients (46%), 95% CI 33–58%, all of whom were neurologically intact. (See Table 3, p. 33.)

Utilizing the pit crew approach will improve outcomes for the citizens and the families you serve by assuring evidence-based therapies are consistently provided. It will also provide a framework to integrate new therapies. While interventions such as continuous compressions and early defibrillation are the cornerstones of resuscitation today, as we continue to improve our knowledge of resuscitation through research the team approach can be easily modified to incorporate future best practices with consistency.

Bonus online content: Read how Wake County EMS developed a checklist to improve cardiac arrest care delivery at www.jems.com/wake-checklist.

Wichita-Sedgwick County, Kansas
Sabina Braithwaite, MD, MPH, is medical director of Wichita-Sedgwick County, Kansas and clinical associate professor of emergency medicine and preventive medicine and public health at the University of Kansas. She’s also the past chair of the American College of Emergency Physicians EMS Committee and of the International Trauma Life Support Board of Directors. She’s been involved in a number of national EMS initiatives, most recently including the EMS Culture of Safety project. She may be contacted at sabina.braithwaite@sedgwick.gov.

Jon E. Friesen, MS, EMT-P, is a paramedic instructor at Hutchinson (Kan.) Community College.

Scott Hadley, MBA, BSN, RN, EMT-P, is the director of Sedgwick County EMS.

Darrel Kohls, BA, EMT-P, is the education manager for Wichita-Sedgwick County EMS System.

Austin-Travis County, Texas
Paul R. Hinchey, MD, MBA, FACEP, is the medical director for Austin-Travis County EMS System and the National Association of EMTs. A former paramedic, he’s board certified in EMS and has 28 years of experience in the industry. He may be contacted at Paul.Hinchey@austintexas.gov.

Michael Prather, EMT-P, is a battalion chief, field training and performance improvement officer and 15-year veteran of Lake Travis Fire Rescue.

Mark Karonika, EMT-P, FP-C, has 18 years of experience in EMS as a flight and critical care paramedic. He’s a 15-year veteran of Austin-Travis County EMS and currently serves as a commander in the special operations division.

Wake County, N.C.
Brent Myers, MD, MPH, FACEP, is the director and medical director of Wake County EMS System.

William D. Holland II, BS, M.Div, EMT-P, is a paramedic and field training officer with Wake County EMS System.

Candice M. Eason, AAS, EMT-P, is a paramedic and field training officer with Wake County EMS System.

Justin Carhart, AAS, EMT-P, is a paramedic and field training officer with Wake County EMS System.

References
As you’ll read in multiple other sections of this supplement, we continue to discern insights into more effective treatment approaches to out-of-hospital sudden cardiac arrest. In reality, we’ve collectively learned more in just the last decade than ever before about the pathophysiology of cardiac arrest.

With considerations about cooling (therapeutic hypothermia), chest compression continuity and alternative ventilation strategies, is there really much to talk about when it comes to something as simple as the rate of chest compressions?

That’s a good place to start and an understandable question. For purposes of this particular conversation, let’s discuss victims who are of adult age. You’re correct in your interpretation of the AHA guidelines released in late 2010.1 How the 2015 guidelines on chest compression rate will change, if at all, is unknown.

There’s been some interesting science published regarding chest compression rates since those 2010 guidelines.2,3 I’m quite sure the clinicians and scientists charged with formulating those 2015 guidelines will certainly take such discoveries into account. The fact is—no surprise here, I think—nothing is very simple when it comes to a condition as dynamic, dramatic and challenging as cardiac arrest.

Key among the latest scientific papers on chest compression rate is work done by Dr. Ahamed Idris and his colleagues in the Resuscitation Outcomes Consortium. In short, Dr. Idris and the research team found that exactly 100 chest compressions per minute didn’t produce the highest number of survivors among the large group of cardiac arrest victims who were treated by systems that participate in the ROC.4

The “sweet spot” of chest compression rate in that review, published in 2012, was much nearer to 120 chest compressions per minute.4 So, you might say that the AHA is still right because 120 compressions per minute fits the definition of “at least 100 times a minute,” although so does 140 compressions per minute, correct?
conditioning or weightlifting? Why does our heart rate rise and breathing increase? We are doing the “Magic C” as I call it—compensating!

That workout-induced tachycardia and tachypnea is getting greater-than-usual oxygen-enriched blood flow to muscles that require it to perform what we're asking of them. As long as we are pulsatile, and your patient is pulsatile, our human bodies will stretch compensation to impressive levels. But, what happens when pulsatile becomes pulseless? Compensation ceases, at least the intrinsic compensation.

So what's the extrinsic compensation during CPR? You. Me. Your partner(s). Bystander(s). CPR is, in one word, compensation.

What percent of compensation do you and I have to attain for a person when we do CPR? 100%! Sobering, huh? We don't even get to outsource 1%; that 100% needs to be the very best it can be, at least according to the best understanding of what works today.

As important as each compression is, the decompression phase is just as important because that's when intrathoracic pressure drops and blood flow can return to the heart to be available for flow from the heart on the next compression. Think about the last sick patient you had in a true tachydysrhythmia with a pulse? Why were they so weak, hypotensive and likely even hypoxic? The rapidity of their pulse prevented good cardiac output and perfusion, both to central and peripheral circulation.

We may not be so worried about peripheral perfusion in cardiac arrest, but if our compressions are going to produce helpful cerebral and coronary perfusion pressures, we have to let enough decompression time occur. That doesn't happen if we compress at 140 times a minute.

So do professionally trained EMTs and paramedics compress that fast anyway? Actually, yes, a lot do. Good-hearted, enthusiastic police officers, firefighters, EMTs and paramedics perform too many compressions. How do I know this? Back in 2011, we discovered in the process of reviewing chest compression fundamentals with each and every EMT and paramedic in the EMS System for Metropolitan Oklahoma City and Tulsa, that without a metronome to guide compressions, nearly 90% of these incredibly well-trained men and women were compressing somewhere between 135–145 times per minute!

That really opened my eyes. It affirmed to me several things: 1) We have EMS professionals in our system who really care about—and work hard at—treating cardiac arrest. Even in training...
November 2014

Advances in Resuscitation

Advances in Resuscitation

scenario, their adrenaline kicks in and they go after it! I had honestly thought if we did start using metronomes set at 120 beeps per minute, directly influenced by that ROC study we’ve been talking about, those metronomes would be needed to speed up the rates. But, I was wrong. The reverse was true; we were compressing too fast and the metronomes would help us to slow down.

It became crystal clear to me we needed to begin using metronomes to change natural compression rate tendencies. This turned out to not just be a positive for the patients, but our crews also, because we were actually able to reduce the physical work necessary in performing optimal manual chest compressions.

“Cool, Dr. G. So just compress at 120 a minute in adults, use metronomes set to that and that’s all there is to it?”

Even with what we’ve discussed so far, there’s more to it. To prove the point, I’ll share with you now that we recently changed our compression rate guideline, and metronomes, to 110 compressions per minute in rate.

“What?!?! How does that make sense based upon what we’ve been talking about?”

Back to the “nothing is really simple when it comes to cardiac arrest” mindset. In our particular system, we currently don’t use mechanical chest compression devices like the Physio-Control LUCAS 2 chest compression system or ZOLL AutoPulse non-invasive cardiac support pump. We use a team dynamic plan for coordinated resuscitation (aka the “pit crew” approach). The most common resuscitation in metro Oklahoma City or Tulsa has 5–8 EMS professionals on scene within 4–10 minutes.

In addition, one of the devices we choose to use in our airway management and cardiac arrest care is the ResQPOD impedance threshold device (ITD) for its capability of reducing intrathoracic pressure during decompression—another important factor in cardiac arrest resuscitation.

Further, because of the emphasis we’ve been placing on the continuity of chest compressions and getting quick feedback to our colleagues about how consistent in rates and continuity that their compressions were or were not in individual resuscitations, we’ve seen our chest compression fraction (time of resuscitation in which chest compressions are occurring) move from a typical 85% to more than 95%.

Without getting too far down in the weeds of science, it’s important to point out that use of mechanical chest compressors and/or the impedance threshold device can influence the basic physiology of hemodynamics produced by compressions.

Through very in-depth conversations that I’ve had over the past few years with the clinical scientists who developed the impedance threshold device, it appears that the ideal compression rate for CPR without an ITD, as reported in the Idris paper, differs from what’s ideal if an impedance threshold device is used in-line in the airway circuit.

It seems the best rate when using an impedance threshold device is much closer to the 100 compression rate per minute; in fact, in subsequent data analysis, the best overall survival in the ROC study occurred in patients who received an active ITD with chest compression scenarios, their adrenaline kicks in and they go after it! I had honestly thought if we did start using metronomes set at 120 beeps per minute, directly influenced by that ROC study we’ve been talking about, those metronomes would be needed to speed up the rates. But, I was wrong. The reverse was true; we were compressing too fast and the metronomes would help us to slow down.

It became crystal clear to me we needed to begin using metronomes to change natural compression rate tendencies. This turned out to not just be a positive for the patients, but our crews also, because we were actually able to reduce the physical work necessary in performing optimal manual chest compressions.

“Cool, Dr. G. So just compress at 120 a minute in adults, use metronomes set to that and that’s all there is to it?”

Even with what we’ve discussed so far, there’s more to it. To prove the point, I’ll share with you now that we recently changed our compression rate guideline, and metronomes, to 110 compressions per minute in rate.

“What?!?! How does that make sense based upon what we’ve been talking about?”

Back to the “nothing is really simple when it comes to cardiac arrest” mindset. In our particular system, we currently don’t use mechanical chest compression devices like the Physio-Control LUCAS 2 chest compression system or ZOLL AutoPulse non-invasive cardiac support pump. We use a team dynamic plan for coordinated resuscitation (aka the “pit crew” approach). The most common resuscitation in metro Oklahoma City or Tulsa has 5–8 EMS professionals on scene within 4–10 minutes.

In addition, one of the devices we choose to use in our airway management and cardiac arrest care is the ResQPOD impedance threshold device (ITD) for its capability of reducing intrathoracic pressure during decompression—another important factor in cardiac arrest resuscitation.

Further, because of the emphasis we’ve been placing on the continuity of chest compressions and getting quick feedback to our colleagues about how consistent in rates and continuity that their compressions were or were not in individual resuscitations, we’ve seen our chest compression fraction (time of resuscitation in which chest compressions are occurring) move from a typical 85% to more than 95%.

Without getting too far down in the weeds of science, it’s important to point out that use of mechanical chest compressors and/or the impedance threshold device can influence the basic physiology of hemodynamics produced by compressions.

Through very in-depth conversations that I’ve had over the past few years with the clinical scientists who developed the impedance threshold device, it appears that the ideal compression rate for CPR without an ITD, as reported in the Idris paper, differs from what’s ideal if an impedance threshold device is used in-line in the airway circuit.

It seems the best rate when using an impedance threshold device is much closer to the 100 compression rate per minute; in fact, in subsequent data analysis, the best overall survival in the ROC study occurred in patients who received an active ITD with chest compression scenarios, their adrenaline kicks in and they go after it! I had honestly thought if we did start using metronomes set at 120 beeps per minute, directly influenced by that ROC study we’ve been talking about, those metronomes would be needed to speed up the rates. But, I was wrong. The reverse was true; we were compressing too fast and the metronomes would help us to slow down.

It became crystal clear to me we needed to begin using metronomes to change natural compression rate tendencies. This turned out to not just be a positive for the patients, but our crews also, because we were actually able to reduce the physical work necessary in performing optimal manual chest compressions.

“Cool, Dr. G. So just compress at 120 a minute in adults, use metronomes set to that and that’s all there is to it?”

Even with what we’ve discussed so far, there’s more to it. To prove the point, I’ll share with you now that we recently changed our compression rate guideline, and metronomes, to 110 compressions per minute in rate.

“What?!?! How does that make sense based upon what we’ve been talking about?”

Back to the “nothing is really simple when it comes to cardiac arrest” mindset. In our particular system, we currently don’t use mechanical chest compression devices like the Physio-Control LUCAS 2 chest compression system or ZOLL AutoPulse non-invasive cardiac support pump. We use a team dynamic plan for coordinated resuscitation (aka the “pit crew” approach). The most common resuscitation in metro Oklahoma City or Tulsa has 5–8 EMS professionals on scene within 4–10 minutes.

In addition, one of the devices we choose to use in our airway management and cardiac arrest care is the ResQPOD impedance threshold device (ITD) for its capability of reducing intrathoracic pressure during decompression—another important factor in cardiac arrest resuscitation.

Further, because of the emphasis we’ve been placing on the continuity of chest compressions and getting quick feedback to our colleagues about how consistent in rates and continuity that their compressions were or were not in individual resuscitations, we’ve seen our chest compression fraction (time of resuscitation in which chest compressions are occurring) move from a typical 85% to more than 95%.

Without getting too far down in the weeds of science, it’s important to point out that use of mechanical chest compressors and/or the impedance threshold device can influence the basic physiology of hemodynamics produced by compressions.

Through very in-depth conversations that I’ve had over the past few years with the clinical scientists who developed the impedance threshold device, it appears that the ideal compression rate for CPR without an ITD, as reported in the Idris paper, differs from what’s ideal if an impedance threshold device is used in-line in the airway circuit.

It seems the best rate when using an impedance threshold device is much closer to the 100 compression rate per minute; in fact, in subsequent data analysis, the best overall survival in the ROC study occurred in patients who received an active ITD with chest compression
First, you’re right. Metronomes are far more important than I first thought. In fact, credit goes to paramedics in our system who pushed the concept. I’ll claim to be smart—smart enough to listen to what proved to be their great idea.7 Those early metronomes came about because not all the responding companies (fire-based) had manual monitor/defibrillators and not all of our monitor/defibrillators had built-in metronomes at the time. And, for my manufacturing colleagues reading this article, I’ll admit some frustration at the lack of their built-in metronomes being changeable in rate. But, I’ll also admit that I understand the frustration that these manufacturers have themselves because they can’t put a “dial the rate up or down” knob or touchscreen on their devices without a time-intensive and costly journey through the Food and Drug Administration review and approval process.

“Wait, Dr. G. So you’re talking a lot about rates, but not so much specifically about metronomes. Seems like those are more important than you first thought and if anything, they’re getting even more important. Why don’t the monitor/defibrillators have metronomes adjustable from 100 per minute? Should we ignore those? And, what metronomes should we be buying?”

“Wait, Dr. G. So you’re talking a lot about rates, but not so much specifically about metronomes. Seems like those are more important than you first thought and if anything, they’re getting even more important. Why don’t the monitor/defibrillators have metronomes adjustable from 100 per minute? Should we ignore those? And, what metronomes should we be buying?”

We made an assumption when the pit crew protocol was finalized and initially implemented, that the medics were providing 120 compressions per minute per our protocol. All of the involved agencies had metronomes at that time and there was nothing to lead us to believe...
In all of the cases in our specific system when the metronome wasn’t used, the compression rate was certainly faster than the 120/min we desired. Interestingly, when the ambulance would go en route to the hospital, rates often jumped almost immediately from around 120 to 130 and above.

After we mounted a concerted effort to have the providers utilize the metronomes and began revealing the patterns in compression rates at our monthly CQI meetings and additionally in emails to the education departments in our system agencies, we found almost immediate elimination of extreme compression rate deviations (e.g., greater than 160/min).

Our typical rate is now 123/min. Keep in mind we’re still rolling out the change to 110/min. This is down from 129/min. It doesn’t sound like much, but there are nearly 100 workable arrests every month in our system and that’s a great achievement by our fire and EMS crews in focusing on hitting that compression “sweet spot” of compressions per minute. We believe it has strongly contributed in increasing our successful resuscitations.

When we participated in a cardiac arrest resuscitation analytics annotation pilot project sponsored by one of our industry partners in February and March of 2014, we found that the compression rates on some cases were alarmingly high while others were at or near 120. So we added a field to the data we collect and the CPR rates have been continuously tracked since that time.

One of the things we found early on was that some of the smaller sized metronomes were not being used for various reasons. In some cases, it was simply because the crews forgot to use them, though in others it was because the Velcro that had been used to attach them to the monitors had become worn and the metronomes either fell off and were lost, or they were simply placed in the monitor case where EMTs and paramedics didn’t know they were relocated. Like they say, out of sight can equal out of mind!

We also learned that environmental noise can cover the sound of the metronome, so, whatever metronome you use, it has to be capable of being heard and/or seen. The metronomes built into the cardiac monitor/defibrillators do seem to solve that problem, but I want to caution that I personally don’t think 100 compressions per minute for all cardiac arrest patients, in all resuscitation practices is the optimal rate as we know it today.

It’s an exciting time in EMS resuscitation. It takes work on everyone’s part to keep pace with the findings we’re putting into practice. Thanks for your commitment to excellence in out-of-hospital EMS medicine by reading this article. Together we’re finding better answers to challenges like cardiac arrest, answers that truly make a life or death difference to people we serve, and when they need those answers most. Keep reading and asking questions because scientific discoveries are happening in EMS medicine now more than ever.

Jeffrey M. Goodloe, MD, NRP, FACEP, is medical director for the Medical Control Board, which provides physician oversight for the EMS System for Metropolitan Oklahoma City and Tulsa, which includes the Emergency Medical Services Authority, the Oklahoma City Fire Department, the Tulsa Fire Department, 20 suburban fire departments and American Airline’s Emergency Response Team in Tulsa. He’s professor and EMS section chief in the Department of Emergency Medicine at the University of Oklahoma School of Community Medicine. He’s also a member of the JEMS Editorial Board and can be reached at jeffrey-goodloe@ouhsc.edu.

References
The performance of high-quality CPR is the primary component in helping us all achieve this goal. Through better measurement, training, and systems-improvement of CPR quality, we can have a significant impact on survival from cardiac arrest.

Learn more in the AHA Statement CPR Quality: Improving Cardiac Resuscitation Outcomes Both Inside and Outside the Hospital at www.heart.org/cprquality
How can you improve your CPR performance?

Mechanical, High-Quality CPR Boosts Neurologically Intact Survival.

CPR—and patient outcomes—can always improve. EMS teams work hard to develop and maintain their skills, but there’s a better way that frees up staff for other lifesaving tasks: the LUCAS® Chest Compression System from Physio-Control. It’s easy to use and designed to deliver high-quality chest compressions for as long as it takes while protecting crew safety.

**Allina Health and Physio-Control**

Allina Health provides care to one million residents across 100 Minnesota communities. In 2013 they responded to 62,000 emergency calls spread out over 1,600 square miles. That’s a lot of people and a lot of territory. Allina needed to ensure everyone could get the best possible treatment—including the best possible CPR.

After deploying the LUCAS system, Allina went from seeing a few cardiac arrest survivors each year to several a month. In the first six months, they had a 5% increase in neurologically intact survival-to-discharge rates. Now they’re among the best in the nation at 50%, much higher than the 38% national average. That’s a big difference when it comes to saving lives.

**Bottom line:** Physio-Control solutions can help you improve your CPR and patient outcomes.

“Crews and first responders love it—it makes the scene of a cardiac arrest go smoother and provides better CPR than we can provide manually.”

—Susan Long, Director of Clinical and Support Services, Allina Health EMS

Learn more. Download the case study at [www.physio-control.com/AllinaHealth](http://www.physio-control.com/AllinaHealth)